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Nr. 4. Frede Hermann and Helge Thomsen: DRIFT-BOTTLE EXPERIMENTS IN THE NORTHERN NORTH ATLANTIC

KØBENHAVN
C. A. REITZELS FORLAG
BIANCO LUNOS BOGTRYKKERI A/S
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DRIFT-BOTTLE EXPERIMENTS

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BY

FREDE HERMANN AND HELGE THOMSEN

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Introduction.

When this work of compiling drift-bottle data was commenced, the intention was to treat only the so far unpublished data for drift-bottles launched by Danish ships after the year 1929. It proved, however, expedient to use statistical methods in order to obtain a reasonably correct picture of average current conditions and also to have the results presented in a clearer form. The original data were, however, in most waters quite inadequate to form a basis for a statistical compilation, and the data used were therefore extended to comprise all drift-bottles launched in the northern part of the Atlantic, in the Norwegian Sea or the Davis Strait.

The data thus collected originate from no less than 27 years, namely from the years 1891, 92, 96, 98, 99, 1900, 01, 02, 05, 06, 08, 10, 11, 12, 13, 14, 16, 19, 28, 29, 31, 32, 33, 34, 35, 38 and 39. The greater part of the data obtained before 1931 have, however, been previously treated, and in the following only a short summary of previous drift-bottle experiments will be given.

All data concerning drift-bottles launched prior to 1902 have been dealt with by C. Ryder[1]). These consist partly of previously published data from the East Greenland Expedition 1891—92 by the "Hekla" and from the "Ingolf" Expedition 1896, partly of data concerning drift-bottles launched by Danish liners to the Faroe Islands, Iceland and Greenland.

Ryder's bottles were launched in the Atlantic north of 56° N. in the waters between Scotland, the Faroes and Iceland, in the Norwegian Sea and the Greenland Sea. During the years from 1891 to 1902 a total of about 800 drift-bottles were launched of which 182 were recovered.

On the basis of these drift-bottle experiments Ryder prepared a surface-current chart which has been extensively used.

The drift-bottles of 1905 were launched and the data compiled by J. N. Nielsen[3]). Of the 80 bottles launched 49 were recovered. All the bottles were launched south of Iceland or between Iceland and the Faroe Islands.

In the years 1906 and 1908 the Denmark Expedition[4]) launched 59 bottles of which

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[2]) C. F. Wandel: Report. The Danish Ingolf Expedition, Vol. I, pp. 18—19. Copenhagen, 1898. Ibid. Drift-Bottles, Vol. I, 4.

[3]) J. N. Nielsen: Contribution to the understanding of the currents in the northern part of the Atlantic Ocean. Medd. fra Komm. for Havundersøgelser. Hydrography. Vol. I, No. 11, Copenhagen, 1908.

[4]) A. Trolle: Hydrographical Observations from the Danmark Expedition. Medd. om Grønland. Vol. 41, pp. 271—426. Copenhagen.

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22 were recovered. All the bottles were set adrift in the Greenland Sea, the Norwegian Sea and the waters between Iceland and the Faroe Islands.

In 1908 drift-bottles were also launched by JOHANNES SCHMIDT[1]), partly in the coastal waters of Iceland, partly in the waters around Rockall Bank. Part of the data were dealt with by JOHANNES SCHMIDT, but the compilation was made so soon after the launching of the bottles that many of them had not been recovered by the time when the work was published. The complete material is published in an appendix to this work.

Of JOHN B. TAIT'S[2]) great mass of drift-bottle data from the years 1910—14 only the bottles from the Faroe-Shetland Channel and the northernmost part of the North Sea have been included in this work. The data have been thoroughly dealt with by JOHN B. TAIT and are included in this work only in support of Danish data.

The data from the years 1916 and 1919 have been published in the Nautical-Meteorological Annual[3]). A total of 409 bottles was set adrift partly in the Irminger Sea, partly in the waters between Iceland and Jan Mayen. Of these bottles 95 were recovered.

In the years 1932, 33 and 34 the "Newfoundland Fishery Research Laboratory" launched a number of drift-bottles in the waters of Labrador and Newfoundland. 21 of these bottles left American waters and drifted across the Atlantic. On account of the incomplete nature of the data concerning these bottles, these data are not included in the appendix, but in the Table, Chapter 4, page 58.

The launching of drift-bottles after 1928 was planned by Å. VEDEL TÅNING, who has also compiled the data from 1928 and 1929[4]), but as a number of the bottles from these years were not recovered until after the compilation, the entire data are given in the appendix to the present work. After 1928 a total of 2675 drift-bottles has been launched from Danish ships, and of these 384 have been recovered. By far the greater part of these bottles were launched in the waters around Iceland and the Faroe Islands. In 1939 a number of bottles were, however, also launched along the coast of Western Greenland, and in 1931 a number between the Azores and Iceland.

In most of the previous compilations of drift-bottle data the distance of drift of the bottles has been measured along the route considered the most probable one, and on the basis of the distance measured and the period between launching and recovery, the average speed of each individual bottle was computed.

Both periods of drift and the speeds of the individual bottles showed, however, so great variations that as a rule it was impossible to determine a definite period of drift or average speed of drift from a place of launching to a place of recovery.

The results of previous drift-bottle experiments, except for those of JOHN B. TAIT, were therefore mainly based upon the relation between places of launching and places of recovery and only to a slight extent upon the periods of drift.

In the present work we may, on account of the relatively large number of observations,

[1]) JOHS. SCHMIDT: The Distribution of the pelagic Fry and Spawning Regions of the Gadoids in the North Atlantic from Iceland to Spain. Conseil Permanent International pour l'Exploration de la Mer, Rapports et Procès-Verbaux des Réunions. Vol. X. Copenhagen 1909.

[2]) JOHN. B. TAIT: The Surface Water Drift in the Northern and Middle Areas of the North Sea and in the Faroe-Shetland Channel. Fishery Board for Scotland: Scientific Investigations, 1930, No. II, 1930, No. IV, 1931, No. III & 1937, No. I, Edinburgh.

[3]) Anon.: Flaskedrift. Det danske Met. Inst. nautisk-meteorologiske Aarbog. 1924, page LIX. København 1925.

[4]) Å. VEDEL TÅNING: Drift-Bottle Experiments in Icelandic Waters. Conseil Permanent International pour l'Exploration de la Mer, Rapports et Procès-Verbaux des Réunions. Vol. LXXII. Copenhagen, 1931.

in many areas carry through a statistical determination of the most frequent periods of drift, which in many cases may be determined with some degree of exactitude. It appears that the most frequent periods of drift in many cases will afford valuable information as to the routes followed by the bottles. Unfortunately, these periods of drift in many cases suffer from an uncertainty which cannot be ascertained, inasmuch as the data from the various areas do not originate from the same years. In most areas drift-bottles have, however, been launched in many different years, so the total data compiled may be expected to give an average condition, wherefore the factor of uncertainty will presumably not be of major importance.

In the following a summary of the data will be given in Chapter I in which regard is paid only to the places of launching and recovery, and not to the periods of drift.

In the subsequent chapters the data will be more thoroughly treated and the periods of drift taken into consideration.

Chapter 1.

Relation between Place of Launching and Place of Recovery.

Recovery Percentages.

In the area under consideration a total of about 5610 drift-bottles was launched, of which 1224 were recovered. On an average 22 % of the bottles launched have been recovered. The recovery percentage varies considerably for the different years, especially due to the fact that different types of drift-bottles have been used. The highest recovery percentage was that of the Ingolf Expedition in 1896 when out of 20 drift-bottles 14 or 70 % were recovered, next come the drift-bottles launched by Dr. J. N. NIELSEN in 1905 when out of 80 bottles launched 49 or 61 % were recovered. In both these experiments the bottles were protected, being first coated with pitch and then packed in wooden cases or wrapped in canvas. In the other Danish experiments ordinary champagne bottles weighted with sand and with sealed corks were used. The lowest recovery percentage was attained in respect of the bottles launched in 1931 in the waters around the Azores when out of 240 bottles launched only 4 were recovered. Of the bottles launched in 1938 and 1939 some have no doubt been recovered without the laboratory having been informed of the fact, inasmuch as a number of them after long periods of drift may have landed in countries which on account of the war were not in communication with Denmark.

Places of Launching and Recovery.

In the Chart, Plate I, the number of recovered bottles is given in each field of 1°. Only four bottles landing on the Azores are not included in this Chart. In the hatched fields bottles have been launched, but none of them recovered. Unfortunately, it is impossible to give recovery percentages for each field, as C. RYDER does not give launching positions for bottles not recovered.

It will appear from the chart that the data are most densely distributed in the Faroe-Shetland area, in the area southeast of Iceland and in a zone along the coast of Iceland. The data between East Iceland and Jan Mayen and in the Denmark Strait are more scattered, but still quite good. The poorest data are those from the Norwegian Sea, the Irminger Sea and the Atlantic Ocean between 60° N. and 55° N. From the waters south of 55° only seven bottles have been recovered despite the fact that about 250 have been launched there.

For the purpose of a summary of the places of landing, the latter are divided as follows:
The coast of Norway is divided into 5 parts: N_1, N_2, N_3, N_4 and N_5.

N_1: The coast south of 62° N.
N_2: - - between 62° N. and 65° N.
N_3: - - — 65° N. and 67°30′ N. Lofoten not included.
N_4: - - — 67° N. and 70° N. 21′ E. and Lofoten.
N_5: - - east of 21° E.

The Faroe Islands are designated by F.

Scotland is divided as follows:

Sc_1: The West Coast of Scotland and the Hebrides.

Sc_2: - Orkneys and the Shetlands.

Sc_3: - East Coast of Scotland.

Ireland is designated by Ir.

Iceland is divided as follows:

I_1: From 63°22′ N.—18°30′ W. to Látrabjarg.

I_2: — Látrabjarg to Cape Langanes.

I_3: — Cape Langanes to 63°22′ N.—18°30′ W.

Further, the Azores are designated by Az., Greenland by Gr., America by Am., North Sea coasts by Ns. and bottles found drifting by Dr.

The waters from which the greatest amount of data emanates are divided into areas A, B, C, D, E, F, G, H, I and K, as shown in the chart, Plate I.

Table 1 contains a summary of the distribution of strandings on the different coast lines of drift-bottles from these launching areas.

The table plainly shows that a very large part of the bottles strand on coasts washed by the streams from the North-East Atlantic current system. Not less than about 70 % of all bottles

Table 1.

Area		N_1	N_2	N_3	N_4	N_5	F	Sc_1	Sc_2	Sc_3	Ir	Ns	I_1	I_2	I_3	Am	Gr	Az	Dr	Total No.
A	No.	5	49	22	27	13	5	1	37	0	0	3	0	0	0	0	0	0	1	163
	%	3	30	14	17	8	3	1	23	0	0	2	0	0	0	0	0	0	1	
B	No.	11	20	13	6	3	0	0	32	2	0	8	0	0	0	0	0	0	0	95
	%	12	21	14	6	3	0	0	34	2	0	8	0	0	0	0	0	0	0	
C	No.	1	20	21	33	34	6	0	9	0	0	0	9	1	9	0	0	0	1	144
	%	1	14	15	23	24	4	0	6	0	0	0	6	1	6	0	0	0	1	
D	No.	1	6	11	14	17	12	0	9	0	0	0	0	5	18	0	0	0	10	103
	%	1	6	11	14	16	12	0	9	0	0	0	0	5	17	0	0	0	10	
E	No.	0	2	1	2	6	0	0	1	0	0	0	0	0	3	0	0	0	1	16
	%	0	12	6	12	38	0	0	6	0	0	0	0	0	19	0	0	0	6	
F	No.	0	3	3	4	4	2	4	2	0	2	3	32	14	3	0	0	0	3	79
	%	0	4	4	5	5	2	5	2	0	2	4	40	18	4	0	0	0	4	
G	No.	0	8	5	9	3	6	4	2	0	7	0	12	1	3	1	0	0	2	63
	%	0	13	8	14	5	10	6	3	0	11	0	19	2	5	2	0	0	3	
H	No.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	36	0	0	37
	%	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	97	0	0	
I	No.	0	4	5	1	1	2	5	2	0	1	0	1	0	3	0	0	0	0	25
	%	0	16	20	4	4	8	20	8	0	4	0	4	0	12	0	0	0	0	
K	No.	0	2	0	11	6	4	6	1	1	2	1	0	0	1	0	0	0	1	36
	%	0	6	0	30	17	11	17	3	3	6	3	0	0	3	0	0	0	3	
Total No. of Recoveries	No.	27	140	111	153	139	54	23	129	14	14	25	153	84	78	2	39	4	35	1224
	%	2.2	11.4	9.0	12.5	11.3	4.4	1.9	10.5	1.1	1.1	2.0	12.4	6.8	6.4	0.2	3.2	0.3	2.9	

recovered have stranded on the coasts of Norway, the Faroes, Shetlands and Orkneys, on North Sea coasts, or have been found drifting in the proximity of these coasts. Of the remainder about 26 % have stranded on the coasts of Iceland. Many of these bottles have been launched close offshore and have had only short routes of drift. Among the Iceland bottles with long routes of drift, great numbers strand on the south and west coast, and also these bottles must be carried by a branch of the North-East Atlantic current system. It may thus be directly seen that a very large part of the total number of bottles will sooner or later enter into this current system. If we consider the individual launching areas similar results will be found as far as the greater part of the areas is concerned. Only in the case of Area H almost all the bottles stranded on Greenland.

In order to obtain a better survey of the data, Table 2 has been computed on the basis of Table 1. In Table 2 N designates bottles stranded on the coast of Norway in percentages

Table 2.

Area		N	$\frac{N_4+N_5}{N}$	F	Sc	Ns	I	A + Gr	Dr
A	%	71.2	34.4	3.1	23.3	1.8	0	0	0.6
B	%	55.8	17.0	0	35.8	8.4	0	0	0
C	%	75.7	61.4	4.2	6.3	0	13.3	0	0.7
D	%	48.6	63.2	11.6	8.7	0	22.3	0	9.7
E	%	68.9	72.7	0	6.2	0	18.7	0	6.2
F	%	17.8	57.0	2.5	10.1	3.8	62.0	0	3.8
G	%	39.7	48.0	9.5	20.6	0	26.0	1.6	3.2
H	%	2.7	0.0	0	0	0	0	97.3	0
I	%	44.0	18.2	8.0	32.0	0	16.0	0	0
K	%	52.7	89.5	11.1	27.9	2.8	2.8	0	2.8
Total No.	%	46.6	51.3	4.4	14.5	2.0	25.6	3.4	2.9

of all recovered bottles, $\frac{N_4 + N_5}{N}$ bottles stranded in N_4 or N_5 in percentages of all bottles stranded on the coast of Norway, Sc bottles stranded in Sc_1, Sc_2, Sc_3 or Ir, Ns bottles stranded on North Sea coasts, I bottles stranded on Iceland, A + Gr bottles stranded in America or Greenland, and Dr. bottles found drifting, all given in percentages of totals recovered, and launched in the area in question. It will be seen that the only areas from which less than one-half of the bottles strand on the coast of Norway are areas F, G, H and I, whence a large number of bottles strands on Iceland, Greenland, in Scotland and Ireland. From Area H only one bottle has drifted to Norway, but it must be observed that all the Greenland bottles were launched close to the coast and in the summer of 1939 shortly before the outbreak of war. If any of the bottles launched there have drifted to European coasts, they have probably had a drift period of several years and may have landed in countries which have been out of communication with Denmark.

Bottles stranded in Norway.

The reason why so large a proportion of the drift-bottles drift ashore on the coasts of Norway must be that rather great water masses stream into the Norwegian Sea and that the main stream for a long distance passes close along the coast of Norway. There is therefore a great probability that a bottle entering this stream will strand on the coast.

The chart, Plate II shows for every field of 1° the percentage of all bottles launched in

the field recovered in Norway. The area between the Faroes and the Shetlands is, however, divided into fields of $^1/_2{}^\circ$ latitude by 1° longitude, conditions in these waters varying considerably with the position.

In the chart curves are plotted approximately limiting the areas whence more than 50 % and more than 75 % of the bottles recovered strand in Norway.

The first area whence more than 50 % of the bottles drift to Norway comprises the entire area with the following exceptions:

1. The waters north, west and south-west of Iceland, whence a large proportion of the bottles strand on Iceland.

2. A small area around the Faroe Islands and

3. The area south of a line north of the Shetlands, Orkneys and Hebrides. The course of the limit west of the Hebrides is uncertain on account of the scarcity of data from this area.

The second area, whence more than 75 % of the bottles drift to Norway, is limited by a curve which north of 66° N. approximately follows longitude 10°W. from N. to S. and then turns west so that the waters between the Faroes and Iceland enter into the area. West of the Faroe Islands the curve has a tongue to the eastward and then again a tongue to the westward extending to 20° W.

It would probably be wrong to conclude that this tongue should contain the main mass of that part of the Gulf Stream which through the Faroe-Shetland Channel passes northwards along the coast of Norway. It can only be concluded that it contains water masses drifting up along the coast of Norway and which have not previously for a long time streamed close by any coast.

If the data had been more numerous and more evenly distributed over the different years and seasons it would be possible to reckon that bottles launched in certain areas could not on their way to Norway pass through areas from which a smaller percentage of bottles drift to Norway. Even on the basis of the available uncertain data, the difference between Area A with 71 % and Area B with 56 % is so great that it may be taken for granted that only a smaller part of the water masses streaming through the Faroe-Shetland Channel can continue through Area B down into the northern part of the North Sea and thence northwards along the coast of Norway. According to Plate II with the analysis of the individual fields there can be no question either of the water masses crossing Area B in a narrow passage. This result seems to be contrary to Tait's assumption that a great part of the water passing through the Faroe-Shetland Channel streams southwards and participates in the northern North Sea circuit.

Further information of the current conditions may be obtained by considering that fraction of the Norway bottles that strand in N_4 or N_5. As such a large proportion of bottles from widely separate areas drift to the coast of Norway, it must be presumed that the masses of water forming the northward current along the Norwegian coast originate from widely separated places. Water masses that unite into this stream at a relatively late stage will, at any rate in the first part of the stream, not be especially well mingled, so that the part of the stream coming from the southernmost waters will run close inshore and keep the water masses from the northern waters farther away from the coast of Norway. This must be expected to cause a difference in respect of various areas in the distribution of strandings along the coast of Norway, so that bottles entering the current closest to the coast will mostly strand in the southern part of the country, whereas bottles carried by the current farther from the coast will usually strand in the northern part. Further, it may be concluded that water masses from areas whence great numbers of bottles strand in the northernmost part of the coast cannot have passed through areas whence large numbers strand in the southernmost part.

It will be noted from Table 2 that the various areas differ greatly. In Area B there are 17 %, in Area A 34 %, in Area C 61 %, in Area D 63 % and in Area E 73 % of all Norway bottles stranding in N_4 or N_5. The water masses passing through Area B, presumably water from the North Sea, form the inner part of the current along the Norwegian coast. Outside of them come the water masses from the Faroe-Shetland Channel, presumably the main mass of the Atlantic water, and outside of that again water from the area between Iceland and the Faroe Islands and the area north-east of Iceland. The difference between areas B and A is so great and the data for these areas so ample that it may be reasonably concluded that at any rate only a smaller part of the stream through the Faroe-Shetland Channel can deviate to the southward and pass through Area B, the same conclusion that was reached by a consideration of the percentage of all bottles drifting to Norway.

Similarly, the difference between A and C indicates that only a small proportion of the water from C can have streamed through the Faroe-Shetland Channel to Norway. As, furthermore, so large a proportion of the bottles from C drift eastwards, it must be taken that rather considerable masses of water stream north of the Faroe Islands into the Norwegian Sea.

Of the other areas, D shows almost the same percentage of North-Norwegian bottles as C, whereas Area E has still more strandings in Northern Norway. As far as the last-mentioned area is concerned, the data available are so sparse that it is hardly possible to draw conclusions from them.

Among the other areas, F and G range between areas A and C as regards the percentage of North-Norwegian bottles. Probably some of the bottles from these areas have passed through Area A and others through Area C on their way to Norway. The possibility remains that some of the bottles have drifted north of Iceland and through Area D into the Norwegian Sea.

As far as areas H, I and K are concerned, the data are so sparse that casual fluctuations become dominant.

Bottles stranding in Ireland.

Along the coast of Ireland 14 drift-bottles have been recovered. The launching places of these bottles are according to the Chart, Plate III to be found in two areas. The former is situated around and SW. of Rockall Bank, whence three bottles drifted to Ireland. This is rather peculiar, as it is generally presumed that the main mass of that branch of the North-East Atlantic current which enters the Norwegian Sea passes between Ireland and Rockall Bank, so the direct route of these bottles would go against the current. It is therefore impossible solely on the basis of the launching and stranding positions of these bottles to give an explanation of the drift of these bottles, wherefore a detailed investigation will be given in Chapter 4, page 60.

The bottles from the latter area have all been launched in rather a narrow strip from the south-western and western coasts of Iceland, across the Denmark Strait and down along the eastern coast of Greenland to Cape Farewell. From this area 11 bottles have been found on the coast of Ireland. The bottles launched along the eastern coast of Greenland must, no doubt, have commenced their drift southward with the East Greenland Polar Current, whereas the latter part of their drift until the stranding on Ireland must have followed the North-East Atlantic current. Somewhere en route the water masses from the East Greenland polar current must have mingled with or gone under the water of the Gulf Stream system, so that the bottles have entered into that system. It is probable that the bottles launched along the coast of Iceland

have entered the same route, having first drifted towards the coast of East Greenland. Otherwise, the bottles should have crossed that part of the branch of the North-East Atlantic current which passes through the Faroe-Shetland Channel.

Bottles stranded on the Western Coast of Scotland.

A total of 23 bottles has stranded on the western coast of Scotland. The places of launching will appear from Plate III. With two exceptions these bottles originate from the same areas as the bottles drifting to Ireland. The two exceptions are a bottle launched north of the Shetlands and one launched NW. of the Orkneys. The former has presumably drifted along the route described by Tait, i. e. it has first drifted with the western part of the great North Sea circuit and then south of the Orkneys to north-western Scotland. The latter has been launched so close to the place of stranding that it must be presumed to have drifted there direct.

Of the remaining bottles 6 originate from the waters around Rockall Bank, 5 from an area west of the Bank and the 10 like the bottles drifting to Ireland from the strip along western Iceland, across the Denmark Strait and along the coast of East Greenland. One of these bottles was, however, launched north of 74° N. The last mentioned bottles must surely have followed the same track as the Ireland bottles, i. e. down to the Gulf Stream and with it to Scotland. The bottles launched at Rockall Bank and west thereof were launched so far to the North that they should have crossed that part of the North-East Atlantic current which passes along Ireland and Scotland and through the Faroe-Shetland Channel provided they had drifted direct to the places of stranding. It would therefore be reasonable to presume that they have taken the same route as the Ireland bottles launched at Rockall Bank. These bottles will be dealt with in a subsequent chapter.

The bottle which drifted from the Faroe-Shetland area to north-western Scotland indicates that there is a possibility that some of the bottles drifting through the Faroe-Shetland Channel will strand on the northernmost part of the west coast of Scotland, but in view of the extremely small percentage of the bottles from this area taking this route, it must be considered highly improbable that bottles launched off Iceland and Greenland will drift to western Scotland by this route.

Bottles stranded on the Shetlands and Orkneys.

On the Shetlands and Orkneys a total of 129 bottles has stranded. See Plate III. Of this total 92 originate from areas A and B and from the waters between the Shetlands and Orkneys. The great number of bottles passing from B to these islands shows that here a south-western current predominates. According to Tait this area should form part of the northern North Sea circuit.

It is a curious fact that so many bottles drift from the northern part of the Faroe-Shetland Channel to the Shetlands and Orkneys. These bottles must in some way have crossed the main stream through the channel. Tait explains the phenomenon by the presumption that a great part of the water masses from the Faroe-Shetland Channel curves down into the North Sea with the western part of the circuit. The bottles should thus follow this circuit to Morray Firth and thence drift northwards along the coast of Eastern Scotland to the places of stranding. This theory is, however, incompatible with the fact previously mentioned that among the Norway bottles from Area B there are considerably fewer strandings in Northern Norway than from Area A. We can only conclude that highly turbulent current conditions prevail in the channel

with a strong intermingling of the water masses across the direction of the main stream. In the same way it may be explained that bottles launched north of the Faroes and east and north-east of Iceland can strand on the Shetlands and the Orkneys. These bottles must have followed the East-Icelandic Current to the waters around the Faroes and then passed across the channel. Thus, these bottles must have crossed both the water masses streaming into the Norway Sea north of the Faroes and the water masses streaming through the Faroe-Shetland Channel.

5 bottles have been launched in the area around Western Iceland and Eastern Greenland. These bottles must have followed the route outlined for the Ireland and Scotland bottles. Also from Rockall Bank and the waters south-east of Iceland bottles have drifted to the Shetlands and Orkneys. We shall revert to these bottles in a subsequent chapter.

Bottles stranded on the Faroe Islands.

54 bottles in all have drifted ashore on the Faroe Islands and one was found drifting close to the islands. See Plate III. Of these, 11 originate from the waters around the islands, 5 from the sea west of the islands, 23 from the area along the east coast of Iceland and north-east of Iceland all the way up to Jan Mayen. 9 originate from the Denmark Strait and the area along the east coast of Greenland, and 6 from the area from Rockall Bank and westward. Finally, 1 originates from the waters south of Greenland as far west as 48° W.

Of the 5 bottles from the waters west of the Faroes the 4 easternmost ones have no doubt drifted eastward to the islands. The westernmost bottle was launched close to the area off South-Western Iceland whence bottles have drifted to Ireland and Scotland. The question as to whether this bottle has drifted the same way as these bottles to the North-East Atlantic Current and thence to the Faroes or whether it has drifted direct to the islands will be determined in Chapter 4.

The bottles launched east and north-east of Iceland must have drifted southwards with the East-Icelandic Current. The comparatively large number of bottles from this area passing to the Faroes shows that this current must either at times pass close by the Faroes or mingle to a considerable extent with the masses of water which from the waters south of Iceland stream north of the Faroes into the Norwegian Sea. A great proportion of the bottles originates from the waters close under the coast of Iceland which shows that if there is a coastal current all the way round Iceland it must either be confined to a very narrow zone or its water must be strongly mingled with water from the East-Icelandic Current so that bottles from the coastal current may pass over into the East-Icelandic Current.

The bottles launched in the Denmark Strait and along Eastern Greenland must, no doubt, have drifted by approximately the same route as that outlined for the Ireland and Scotland bottles.

Among the bottles launched at the most southerly points 4 originate from the waters at Rockall Bank. These bottles were launched simultaneously with the bottles that drifted to Ireland, Scotland, the Shetlands and Orkneys. The bottles launched at Rockall Bank have thus apparently drifted in almost diametrically opposite directions. We shall revert to this peculiar phenomenon.

Bottles stranded on Iceland.

The Chart, Plate IV shows in each field of 1° the number of bottles stranded in I_1, I_2, and I_3 respectively. In I_1 153 bottles in all have been recovered, in I_2 78 and in I_3 84. It will appear from the chart that the greater part of these bottles originate from the coastal waters

around Iceland. These bottles will be dealt with in the chapter on the Coastal Current around Iceland.

The remaining bottles landing on the coast of Iceland may naturally be divided into three parts, namely: 1. Bottles launched north of Iceland, 2. Bottles launched south of Iceland and 3. Bottles launched in the Denmark Strait, Irminger Sea and along the east coast of Greenland.

From the northern area 12 bottles have stranded on Iceland. Of these 4 landed on the north coast, 7 on the south-east coast and 1 on the west coast. This may indicate that the southward current in the Greenland Sea at first has a slightly westward direction. Probably the origin of the East-Greenland and the East-Icelandic Currents here form a broad stream which then divides north of Cape North into the south-westward East-Greenland Current and an eastward—subsequently southward—current along the northern and eastern coasts of Iceland. The bottle stranded on the west coast is that launched in the westernmost position. This bottle has probably got into the East-Greenland Current and thence in some way drifted to the west coast of Iceland.

Of the bottles launched south of Iceland 12 have landed in I_1, 1 in I_2 and 8 in I_3. As might be expected the bottles launched in the most easterly positions predominate among those landing in I_3 and those from the most westerly positions in I_1. Usually, these bottles have stranded north-west of their places of launching. The one bottle that has drifted to northern Iceland must have drifted west of Reykjanes and northwards past Látrabjerg.

Most of these bottles originate from Area C whence, as will appear from Table 2, 76 % of all bottles launched have stranded in Norway. As previously mentioned this fact indicates a predominating eastward drift in this area. The question whether this may be compatible with the northwestward drift of the Iceland bottles will be examined in a subsequent chapter. It is observed that the southernmost bottle of those under consideration was launched about 150 miles northwest of Rockall Bank. In general, the bottles launched around Rockall Bank indicate extremely turbulent current conditions there, the bottles apparently drifting in almost all possible directions. From the waters in the Denmark Strait and the Irminger Sea 45 bottles have drifted ashore in I_1, 15 in I_2 and 8 in I_3. It must be observed that with two exceptions all the bottles landed in I_2 have stranded west of 21° W., so only few of the bottles from the Denmark Strait pass into the current along the north coast of Iceland.

A number of the bottles stranding in I_1 has no doubt drifted to the place of stranding direct, but as the bottles have been launched in the area whence a number of bottles drifted to Ireland and Scotland, it must be presumed that many of them have commenced on the same route as that outlined for the Ireland bottles. The Iceland bottles should thus somewhere return to the Irminger Current and so make an entire circuit. The extent of this hypothetical circuit cannot, of course, be determined by this rough analysis.

Of the 8 bottles stranding in I_3, 1 has stranded on the south coast in 14°50′ W., whereas the remainder have stranded on the south coast west of 17°30′ W. These bottles must also have passed over into the Irminger Current and been carried to the place of stranding by that current.

Bottles stranded in Western Greenland and North America.

Apart from the bottles launched close to the coast of Western Greenland, 3 bottles have stranded in Western Greenland and one has been found drifting close to the coast. Of these, 3 have been launched along the coast of East Greenland, the northernmost north of 77° N. and the southernmost south of 62° N., whereas the third was launched at the mouth of Scoresby

Sound. All these bottles must have drifted southwards to Cape Farewell with the East-Greenland Current and then northwards along Western Greenland with the West-Greenland Current. The fourth bottle was launched west of the Vestman Islands, Iceland and stranded in the southernmost part of Western Greenland. The first part of the drift of this bottle must have been identical with that outlined for the Ireland bottles, i. e. northwards and westwards with the Irminger Current and then southwards with the East-Greenland Polar Current.

On the coast of North America two bottles have stranded. One was launched in Southeast Greenland and stranded on the coast of Labrador, whereas the other was launched southwest of Reykjanes and also stranded in Labrador. It is reasonable to presume that the first part of the drift of these bottles was approximately identical with that of the Greenland bottles, so that the bottles have entered the northward West-Greenland Current. Thence the bottles must have drifted westwards into the Denmark Strait until they have entered the Labrador Current with which they have been carried to Labrador and Newfoundland, respectively.

Chapter 2.

The Faroe-Shetland Channel and the Norwegian Sea.

The Faroe-Shetland Channel.

The data dealt with in this part consist of those concerning the bottles launched in Area A. Chart 1, Plate I. In all essentials the data are those treated by JOHN B. TAIT concerning bottles launched in the years 1910, 11, 12, 13 and 14; besides there are data for bottles launched by Danish ships during the years 1899, 1900, 1934 and 1935.

As the majority of the bottles launched in the area has been dealt with in detail by JOHN B. TAIT, we shall confine ourselves to attempt to give a summary of the drift of the bottles. As will appear from Table 2, Chapter 1, the Norway bottles dominate in this area and their drift will be analysed first.

Bottles drifting to Norway.

It will be of great importance if the course of the drift from Faroes-Shetlands to Norway might be cleared up, as it must be presumed that a great part of the bottles which from the western launching places drift to Norway must pass through the Faroe-Shetland Channel in their course.

The distances of drift of the drift-bottles are measured in nautical miles by means of the scale given in Fig. 1 which is presumed to follow the main stream approximately. In order to find the rate of the current along the route, the measured distance in nautical miles is plotted in a diagram as a function of the number of days the bottles have been drifting. If in such a diagram a curve is drawn through the points corresponding to the fastest bottles, the inclination coefficient of the curve will show the rate of current corresponding to the fastest bottles in the various stages of their course.

By means of a provisional diagram in which no regard is paid to differences between the places of launching, the rate of current in the channel proper is determined at about 10 miles per day. By means of this rate the number of days the bottles would have been en route if launched at zero on the scale is computed. The distance of drift is then measured from zero to the place of stranding parallel to the scale. By means of these data the points in the diagram in Fig. 2 are obtained. The diagram does not, however, include the 5 bottles that have stranded south of 62° N. nor the 12 bottles which have had a time of drift of more than 500 days. In this diagram points with the same ordinate will correspond to bottles stranding in the same area of the coast of Norway, so the diagram will give an immediate picture of the spread in times of drift for bottles with approximately identical places of launching and stranding. It will be seen that the spread becomes very considerable in proportion to the time of drift of the fastest bottles. Four causes of this spread may be considered:

1. The period of time for which the bottles have been lying undiscovered on the beach may be considerable in proportion to the actual time of drift.

2. The rate of the current may have been subject to great variations according to the time. Partly, the current may have varied with the season, partly it may have varied from year to year.

3. The bottles may have followed different routes. Thus a number of the bottles may

Fig. 1. Principal areas of the Norwegian Sea and scale in naut. miles for measuring drift distances from the Faroe-Shetland Channel to Norway.

have drifted along routes longer than the distance given by the scale. In this connection the route mentioned by Tait, down through the northern part of the North Sea, is especially considered.

4. The rate of current may vary greatly with the geographical position so that drift-bottles the routes of which differ but slightly may have widely different times of drift.

Each of these possibilities will now be considered separately.

As far as the first possibility is concerned no determination of the average waiting period on the coast of Norway can be made, data concerning drift-bottles launched close to the coast being lacking. In the treatise on the coastal current around Iceland it was ascertained (page 37) that the average waiting period for bottles stranded on Iceland varies from 8 to 20 days according

to the density of population on the coast. As the Norwegian coast is probably more densely populated than that of Iceland, it is probable that the average waiting time for bottles stranded on the Norwegian coast will be considerably less than 20 days. The spread arising out of the fact that the bottles lie undiscovered on the beach for some time should thus be relatively inconsiderable. It may, however, very well be considered possible that some few bottles have stranded at deserted spots where they have been lying undiscovered for a long time. This may explain that some of the bottles have not been found until after very long periods of drift.

As far as the second possibility is concerned rather considerable variations in the rate

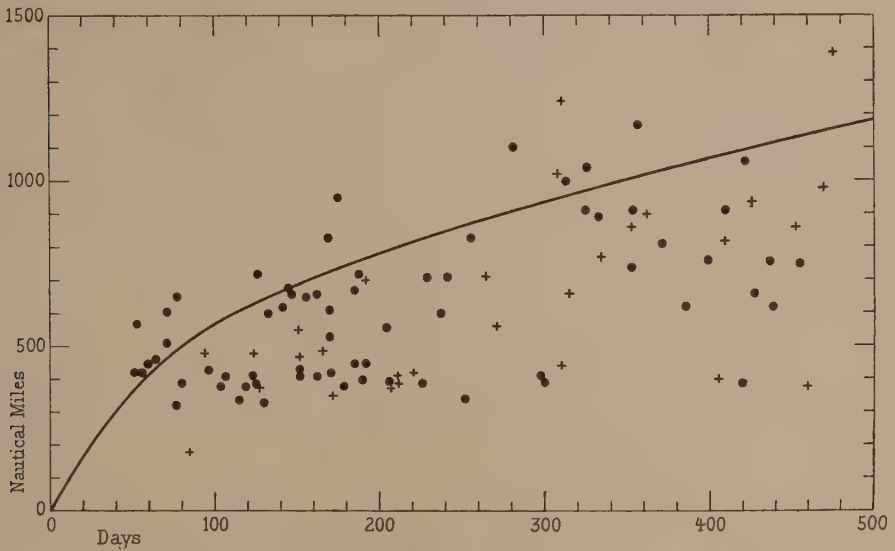


Fig. 2. Distances of drift plotted against number of days for the drift from the Faroe-Shetland Channel to Norway. +: bottle liberated at the same place and time as bottles drifting to the Shetland islands.

of current with time may doubtless occur. The short-term variations will, however, to a great extent be eliminated by drift-bottle observations, the periods of drift being 50 days or more.

The seasonal variations will be investigated with a view to the distribution of the periods of drift, page 21. It will appear that the spread within the individual seasons is practical identical with the total spread, so the seasonal variation is not by far sufficient to explain the spread. It also appears that even if we consider only bottles launched at the same time and in the same station, we will as a rule have a spread in times of drift of the same magnitude as the spread shown in the diagram.

The main cause of the spread must therefore be found in one of the possibilities mentioned in 3 or 4.

If a large part of the bottles had drifted by a route considerably longer than the direct route to Norway, the points in the diagram might be expected to group themselves around several curves, of which the curve for the direct routes should be capable of being extended backwards through the zero of the diagram, whereas the other curves should lie below that for the direct track and be parallel to the latter. The points in the diagram are, however, so scattered that it is impossible to discern any groups. Among tracks other than the

direct one, that described by Tait, down through the northern part of the North Sea, is particularly interesting. Doubtless, a number of bottles have drifted that way, but as mentioned in Chapter 1, page 10, this is probably an inconsiderable part of the bottles. From many stations in the Faroe-Shetland Channel bottles have drifted to the Shetlands and the Orkneys. It might be expected that a relatively large part of the Norway bottles launched on the same stations would commence with a southward drift, so that they would drift around in the northern North Sea circuit before they enter the northward current along the coast of Norway.

In the diagram points corresponding to Norway bottles launched at these stations are marked by a cross. It will be seen that these points are rather evenly distributed among the rest. Even among the fastest bottles there are some launched from these stations. It cannot therefore be taken for granted that Norway bottles from a station will drift down through the North Sea, even if bottles from the same station drift to the Shetlands and Orkneys.

It must therefore be concluded that the principal cause of the great spread must be ascribed to a strong variation in rate of current with the geographical position. From dynamic computations of the rates of current along the coast of Norway[1]) it will appear as a general rule that the actual central stream is rather narrow, while in a belt on either side of the central stream there are weaker currents or even back-currents. It is therefore probable that only the fastest bottles have followed the central stream throughout their track, whereas the preponderant part of the bottles which has had longer periods of drift has drifted into waters with weaker currents or has been retained for some time in eddies or in areas with back currents.

It will be noted from the diagram that some points are lying considerably higher than all the rest. These points probably represent bottles which have followed the central stream at times when the rate has been abnormally high. In the diagram a curve has been drawn through the points corresponding to the maximum rates, bottles with extraordinarily high rates having, however, been disregarded. This curve will probably approximately represent the average course of the central stream along the coast of Norway.

The coefficient of inclination of this curve should then give the rates of current at different places along the scale plotted. These rates are given in the below table.

Distance in nautical miles	0	300	600	900	1100
Rate in miles per day	10	6.3	2.1	1.5	1.2

The rates thus calculated are, of course, highly uncertain, but they afford some idea of the rate of the actual central current along the coast of Norway. It will be seen that the rate decreases rather abruptly between 500 and 600 on the scale, i. e. south of the Lofoten. If it may be assumed that the transport of water of the stream is approximately proportional to the rate, this must mean that rather large masses of water leave the stream here and drift westwards. This is in conformity with Fridtjof Nansen and Helland-Hansen's Current Chart in "The Norwegian Sea".

By means of the diagram we may thus obtain a measure of the maximum rate of current. The determination is, however, very uncertain, and as a rule it is rather the most frequent

[1]) B. Helland-Hansen and F. Nansen: The Norwegian Sea. Report on Norwegian Fishery and Marine-Investigations Vol. II, No. 2. Kristiania 1909.

[2]) B. Helland-Hansen: The Sognefjord Section. Oceanographic Observations in the Northernmost Part of the North Sea and the Southern Part of the Norwegian Sea. James Johnstone Memorial Volume. Liverpool 1934.

periods of drift we desire to obtain than the shortest ones. In order to find the most frequent periods of drift and to obtain a better survey of the entire mass of data, the frequency distribution of the periods of drift of the bottles will now be investigated. In order to obtain sufficient data for these statistics it will be necessary to comprise all the bottles stranded in a large area of the Norwegian coast in one curve. In Fig. 3 curves have thus been drawn for bottles stranded in N_2, for bottles stranded in N_3 and for bottles stranded in N_4+N_5. In these curves the period

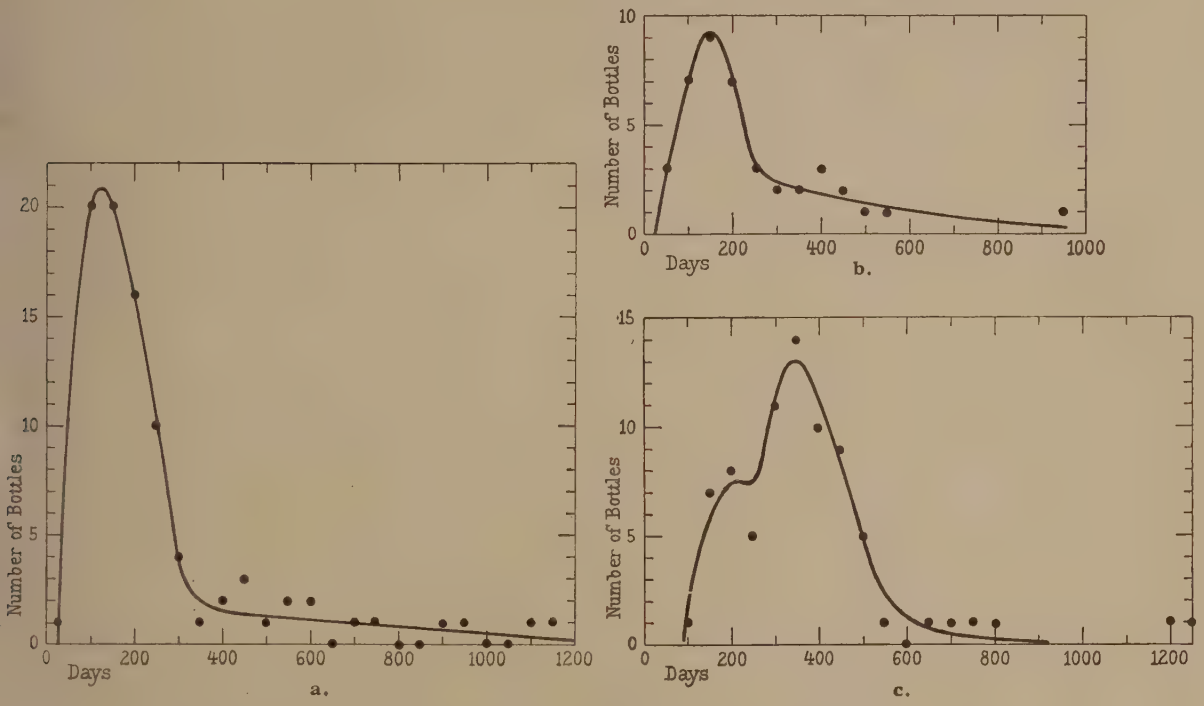


Fig. 3. Frequency distribution of drift time for the drift from the Faroe-Shetland Channel to Norway. a. Bottles recovered on N_2. b. Bottles recovered on N_3. c. Bottles recovered on $N_4 + N_5$ (Plate I).

of drift is the abscissa, while the number of bottles stranded within intervals of 100 days is the ordinate. In order to eliminate accidental variations a system of grouping with overlapping intervals has been used, partly the intervals: 0—100 days, 101—200 days etc. and partly the intervals 51—150 days, 151—251 days etc. By the most frequent period of drift we then understand the period corresponding to the maximum of the curve.

For bottles stranded in N_2 a maximum of about 125 days is obtained. The curve of distribution for the bottles is rather smooth. If a large group of the bottles had followed the route down through the northern part of the North Sea, we might have expected to find at any rate a sign of a secondary maximum, as it must be presumed that the period of drift of these bottles on an average would be considerably higher than for bottles drifting to Norway direct. It is, of course, possible that the curves of distribution for the two groups overlap to such an extent that they cannot be discerned in the curve of total distribution.

On the distribution curve for bottles stranded in N_3, the maximum lies at a period of drift of about 150 days, so the curve is shifted about 25 days in relation to the curve for N_2, it is, however, more uncertain than the latter, the amount of data being less.

The curve of distribution for bottles drifting to $N_4 + N_5$ is more irregular than the two curves first described. The curve shows indications of two maxima, one at about 200 days and the other at about 350 days. This peculiar fact may be due to the bottles forming the latter maximum having drifted once round a circuit before stranding. According to Fridtjof Nansen and Helland-Hansen's current chart in "The Norwegian Sea", there should be such a circuit both in the northern and in the southern parts of the Norwegian Sea. This explanation of the phenomenon is, however, hardly tenable, inasmuch as it might then be expected that the former maximum representing the direct bottles should be greater than the second maximum representing the bottles drifting once round the circuit, but as will appear from the curve, the second maximum is absolutely predominant.

The phenomenon cannot either be explained by the fact that bottles forming the first maximum have been launched in a year or at a season with abnormal current conditions. It appears namely that the bottles forming the first maximum have been launched in six different years and that the bottles forming the second maximum principally originate from the same years. In the distribution according to the seasons there is not much difference either between the two groups of bottles.

If the irregularities cannot be considered as purely accidental, the explanation must rather be sought in an irregular distribution of the places of stranding.

If we consider the distribution of the places of stranding in the first maximum, i. e. for bottles having a period of drift of less than 300 days, it will appear that of these 12 bottles 9 have stranded in the southern part of the Lofoten, in other words in the southernmost part of N_4. Of the 23 bottles having periods of drift of between 300 days and 500 days and forming the second maximum, only 6 have stranded south of 69° N., whereas the remaining 17 are distributed over more northerly stranding places.

This may indicate that the curious distribution of the periods of drift is due to the fact that a relatively large number of strandings is concentrated in the southern part of N_4, the remainder being rather regularly distributed over the rest of the stranding area.

If we plot an adjusted curve for the bottles stranding in N_4+N_5 we obtain a maximum of about 300 days.

There is thus a considerable difference in the most frequent periods of drift between bottles stranding in N_2 and those stranding in N_4+N_5. As mentioned in Part 1, page 10, there is a great difference between areas A and B as regards the percentage of Norway bottles drifting to N_4+N_5. This great difference indicates that only a small number of the bottles passing down through the North Sea will get as far North as N_4 and N_5. Within the group of bottles which drift from the Faroe-Shetland Channel to N_4 and N_5, there should in other words be fewer that have drifted down through the North Sea than in the group drifting to N_2 and N_3. If a considerable number of bottles of the latter group had drifted down through the North Sea a considerably smaller difference in the most frequent periods of drift should have been expected.

From these investigations it does not appear probable that any large mass of the water streaming through the Faroe-Shetland Channel continues down through the North Sea. It is, however, on the basis of the available data impossible to determine how large a part of the water masses moves one way and how much the other way.

The Variation of Current with the Seasons.

The existence of an annual variation in the current from the Faroe-Shetland Channel to Norway might be considered possible. In his drift-bottle investigations TAIT arrived at the result that in May and June the entire stream through the Faroe-Shetland Channel passes down through the North Sea whereas in August a great part of the stream passes direct to the coast of Norway. If this were correct, a relatively smaller number of bottles might be expected to drift to $N_4 + N_5$ in the early summer than in the late summer. From the below table it will, however, be seen that the opposite is the case, so the present investigation would seem to be contrary to the result obtained by TAIT.

Months of liberation	$100 \cdot \frac{No\ (N_4+N_5)}{No\ (N_2+N_3)}$
April, May, June	43 per cent
July, August, September	30 - -
Other months	24 - -

No $(N_4 + N_5)$ = Number of bottles stranded in $N_4 + N_5$
No $(N_2 + N_3)$ = — - — — - $N_2 + N_3$

In order further to investigate whether an annual variation exists in the current from the Faroe-Shetland Channel to Norway, the curves in Fig. 4 have been plotted. Fig. 4a shows the curves of distributions of bottles stranded in N_2 and N_3 and launched partly in April, May and June, partly in July, August and September and partly in the remaining six months of the year. Fig. 4b gives corresponding curves for bottles stranding in N_4 and N_5.

From the curves in Fig. 4a it would appear as if the most frequent period of drift is shortest for bottles launched in July, August and September, the differences in the periods

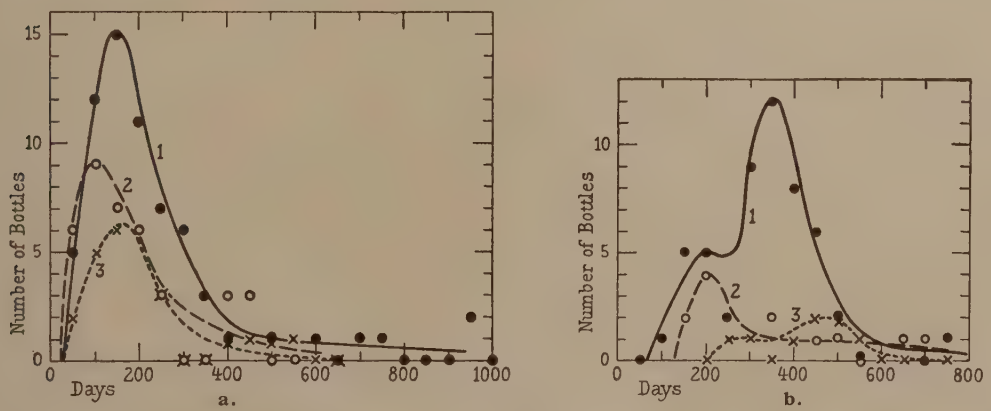


Fig. 4. Frequency distribution of drift time for the drift from the Faroe-Shetland Channel to Norway for bottles launched at different times of the year. a. Bottles recovered on $N_2 + N_3$. b. Bottles recovered on $N_4 + N_5$. Curves marked 1: Bottles launched in April, May and June. Curves marked 2: Bottles launched in July, August and September. Curves marked 3: Bottles launched in the other months.

of drift are not, however, so great that they cannot be explained by the uncertainty due to the rather incomplete data.

As regards the curves in Fig. 4b only the data for April, May and June are sufficient to give a reasonably effective curve of distribution. Like the curve in Fig. 3b, this curve shows indications of two maxima, one at about 200 days and one at about 350 days. In the curve for July, August and September there is an indication of the same two maxima. These maxima cannot therefore be due to the fact that the rate of current varies with the season.

On the whole the curves indicate that the bottles get somewhat quicker to N_2 and N_3 in July, August and September than in April, May and June, and it also looks as if a somewhat greater percentage of the bottles launched in April, May and June will strand in northern Norway than of bottles launched at other seasons.

These differences are, however, not especially pronounced and the possibility remains that they are due only to statistical inaccuracy.

These statistics take no account of the 5 bottles stranded in N_1. All the bottles stranded between 60° N. and 62° N. after the following periods of drift: 93 days, 115 days, 125 days, 200 days and 286 days. Some of these bottles have no doubt arrived at the place of stranding from the South and must thus have drifted around in the circuit in the northern North Sea described by Tait.

In connection with the Norway bottles mention may be made of two bottles found adrift. They were both launched on March 28th, 1935, one was launched in 61°30′ N.—6°05′ W. and recovered in 61°04′ N.—0°45′ W. after 106 days, the other was launched in 61°30′ N.—5°40′ W. and recovered in 62°03′ N.—0°40′ W. after 85 days. Thus, the places of launching and the places of recovery of the two bottles are close together. The direct distance between the places of launching and recovery of both bottles is about 190 miles, so the bottles have had an average speed of 1.8 and 2.2 miles per day respectively. These small speeds seem to indicate that the bottles have been retained for some time in the channel area, possibly in an eddy south of the Faroes.

Bottles drifting to the Shetlands and Orkneys and to North Sea Coasts.

As mentioned in Chapter 1, a total of 37 bottles or 23 % of all bottles from Area A stranded in the Shetlands or the Orkneys. The periods of drift of these bottles vary from 8 days to 227 days and there seems to be no relation between points of launching and the periods of drift. Tait explains this great variation in periods of drift by the assumption that a great number of the bottles will drift down through the north-western part of the North Sea to Moray Firth where they are retained for some time in an eddy before they again drift northward to the point of stranding. Accordingly, the bottles should have drifted a long distance along the coasts of Moray Firth. If this route were correct it might be expected that at any rate part of the bottles would be recovered at Moray Firth, which is not the case. The above-mentioned bottles that have been found drifting show that bottles may sometimes be retained for long periods in the channel area, so it is probable that some of the Shetlands bottles have been retained in eddies in the channel proper, and the long periods of drift may be due to this fact.

The places of launching of these bottles are evenly distributed throughout the channel, so at any rate some of the bottles must have drifted across the average main stream.

By way of an explanation of this phenomenon it might be imagined that the entire stream through the channel in periods passed close by the Shetlands and Orkneys down into

the North Sea. The Norway bottles launched at the same times and places as the Shetlands bottles should then also drift down through the northern North Sea and it might be expected that this would be shown by a larger average period of drift for these bottles than for other Norway bottles. As stated in the mention of the diagram in Fig. 2, such a difference cannot be ascertained. It must therefore be concluded that very turbulent current conditions prevail in the Faroe-Shetland Channel, so that water masses, perhaps in the form of moving eddies, may cross the main stream from North to South. There are no indications of a corresponding motion from South to North. The 5 bottles stranding in the Faroe Islands have all been launched in the northern part of the channel.

In connection with the Shetlands and Orkneys bottles mention may here be made of the three bottles which from the Faroe-Shetland Channel drifted to North Sea coasts. Two of these bottles stranded on the west coast of Sweden and the third on the west coast of Jutland. The periods of drift were 175, 429 and 249 days respectively. These three bottles have no doubt commenced on the same track as the Shetlands bottles and have drifted past the Shetlands down into the North Sea.

These three bottles show that part of the water masses from the Faroe-Shetland Channel streams down through the North Sea, but as already mentioned in the analysis of the Norway bottles, this is probably only a small proportion of the water masses streaming through the Faroe-Shetland channel.

The Norwegian Sea and the Greenland Sea.

This part will deal with the area north of the boundary line plotted in Fig. 1. The bottles used in the analysis of the coastal current around Iceland are, however, not included. From the entire area 204 bottles have been found. The following table shows a summary of the number of bottles recovered at the various places of stranding:

Norway	Faroes	Shetlands & Orkneys	Iceland	Greenland	Western Scotland
128	27	17	23	2	1

Besides, 6 bottles were found adrift.

As will be seen, by far the greater proportion stranded on the coast of Norway, and as mentioned in Chapter 1, the greater part of these bottles stranded north of the Lofoten. In the analysis of the periods of drift of the Norwegian Sea bottles we will therefore commence with an analysis of the Norway bottles.

Periods of Drift of the Norway Bottles.

The areas having the most complete data are divided into fields which in Fig. 1 are marked a, b, c and d. For each of these fields the distribution of the periods of drift of the Norway bottles will be examined in the same way as in the case of the Faroe-Shetland channel bottles. The number of bottles is not, however, sufficient to allow of an investigation of the variations in periods of drift with the seasons. The curves of distribution for the various fields will be found in Fig. 5.

From Field a 22 bottles have stranded in $N_4 + N_5$. The curve of distribution of these bottles shows a clear maximum between 250 and 300 days, in other words almost the same period as that of the bottles from the Faroe-Shetland Channel. In $N_2 + N_3$ only 8 bottles have stranded, so the curve of distribution in respect of these bottles will be very uncertain.

From Field b 25 bottles have stranded in $N_4 + N_5$, 15 in $N_2 + N_3$ and 2 in N_1. The curve of distribution for the bottles stranded in $N_4 + N_5$ shows two maxima, one of 225 days and one of 375 days. It must be noted that most of the bottles forming the former maximum were launched in the latter half of the summer of 1919, whereas the bottles forming the latter maximum were launched in other years. This peculiar distribution may therefore be due to the fact that the rates of the currents have been abnormally high during the latter half of the summer of 1919. An adjusted curve gives a maximum of about 300 days, or slightly more than that for Field a.

The curve for the bottles drifting to $N_2 + N_3$ shows a rather abrupt maximum at about 225 days. The two bottles drifting to N_1 had periods of drift of 172 and 948 days respectively.

Of the bottles launched in Field c, 17 were recovered in $N_4 + N_5$ and only 6 in $N_2 + N_3$. The curve for the bottles stranding in $N_4 + N_5$ shows a rather abrupt maximum of about 225 days, which means that the most frequent period of drift from this field to Northern Norway seems to be less than that from fields a and b. It must, however, be observed that all the bottles from Field c like the bottles forming the first maximum in the curve for Field b have been

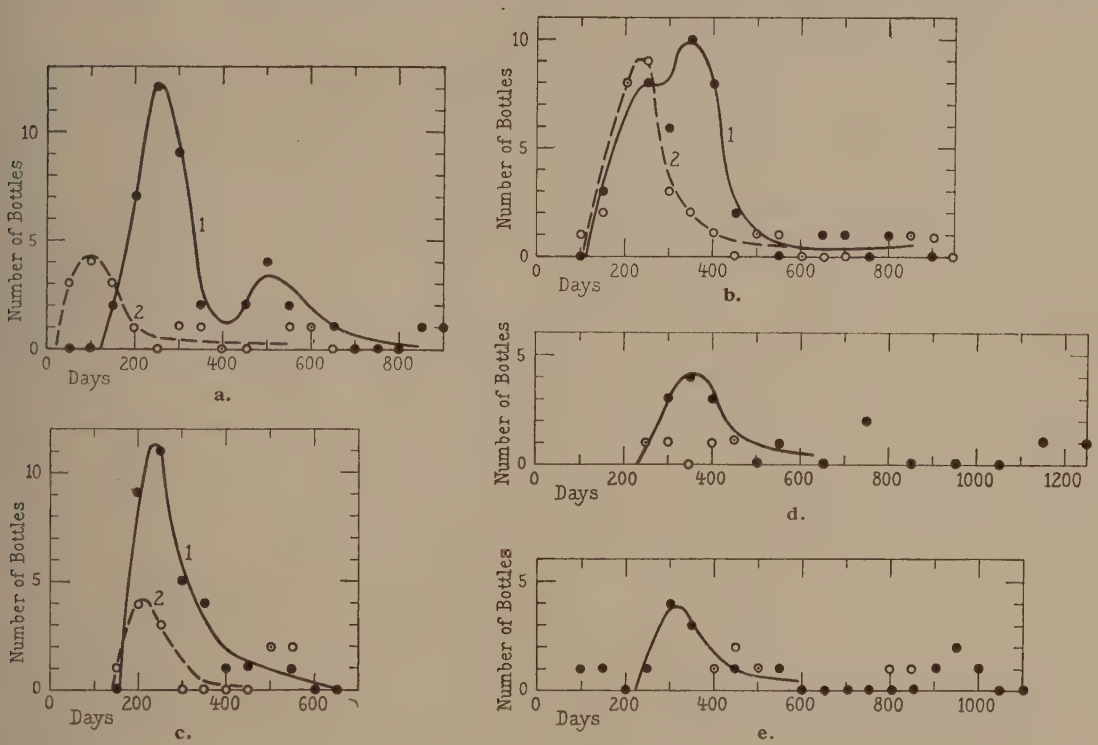


Fig. 5. Frequency distribution of drift time for bottles launched in the areas a, b, c, d, and e (Fig. 1) and recovered on the coast of Norway. ●——●: Bottles recovered on $N_4 + N_5$. ○ - - - ○: Bottles recovered on $N_2 + N_3$ (Plate I).

launched in the latter half of the summer of 1919. It thus appears as if the current rates at that time have been abnormally high.

From Field d 11 bottles have stranded in $N_4 + N_5$ and only two in $N_2 + N_3$. There is an indication of a maximum of about 350 days, in other words, of about the same period of drift as that for Field b. It is therefore probable that the greater part of the water masses from Field d streams through Field b, i. e. north-east of Iceland and into the Norwegian Sea.

Finally we consider the bottles from Field e. From this area 8 bottles have stranded in $N_4 + N_5$ and one was found adrift off N_5. Only 3 bottles have stranded in $N_2 + N_3$. Fig. 4e shows the distribution of the periods of drift, but, of course, a curve of distribution cannot be plotted with any degree of accuracy on the basis of such meagre data. There is an indication of a maximum at about 300 days.

On the whole, there does not seem to be any discernible difference between the most

frequent periods of drift of the bottles which from these areas drift to Norway. Somewhat longer periods of drift might have been expected for the northern areas than for the southern ones, provided the bottles followed the generally accepted route southward along the east coast of Iceland and thence north of the Faroe Islands towards the Norwegian coast. That no difference can be found may be due to the fact that a number of bottles have drifted by a more northerly route than that outlined. The possibility remains that the cause may be ascribed solely to the inaccuracy due to the scarcity of data.

The data dealt with in this part comprise 120 of the 128 Norway bottles from the Norwegian Sea. Of the remaining 8 bottles 7 were launched east of the fields b and c. These few bottles are scattered over so large an area that they can afford no information as to current conditions supplementary to that obtained by the investigation of fields b and c. The last bottle was launched in 69°52′ N.—19°00′ W. and stranded in N_2 after a period of drift of 979 days. This bottle was launched so far to the west that there is a great probability that it has been carried southward with the East-Greenland Polar Current. The bottle will then far south have passed into the North-East Atlantic Current which has carried it to the place of stranding.

Bottles from the Norwegian Sea drifting to Iceland.

Of the 23 bottles from the Norwegian Sea stranding on the coast of Iceland, 10 were launched due east of Iceland, 8 between East Iceland and Jan Mayen, 3 north-east of Jan Mayen between 74° N. and 75° N. and, finally, one north of Western Iceland and one in Scoresby Sound in East Greenland.

Of the 10 bottles launched east of Iceland only 2 were launched outside of the shelf. These two bottles stranded almost due west of the places of launching after periods of 60 and 85 days respectively, so in all probability they have drifted directly westwards. These bottles have evidently drifted across the average direction of drift, as most bottles from this area drift to the Faroes and Norway. The wind observations from the Berufjord in East Iceland and from Grimsey show that easterly winds prevailed during the period after the launching of the bottles. This is probably the cause of the westerly direction of their drift.

As mentioned, the remaining 8 bottles were launched on the shelf, but on account of their long periods of drift they have not been included in the chapter concerning the coastal current around Iceland. Seven of these bottles stranded in Southern Iceland and only one in Eastern Iceland. This one bottle has drifted only 50 miles in 688 days. The short distance and long period of drift indicate that the bottle has been lying for a long time on the beach before it was discovered. With respect to the seven South-Icelandic strandings there are great differences in the periods of drift. For three of the bottles the periods range between 272 and 336 days and for the remaining four between 663 and 1106 days. It is probable that all these bottles for shorter or longer periods have stayed outside the area of the coastal current. We shall revert to these bottles in the paragraph on the waters south of Iceland.

Of the 8 bottles which from the waters between Jan Mayen and East Iceland drifted to Iceland, 7 have stranded in East and South Iceland and one in Northwest Iceland. The last-mentioned bottle was launched in about 68° N.—10° W. and stranded close to Cape North after a period of 305 days. This bottle was launched almost simultaneously with the two bottles east of Iceland which seems to indicate that like them it has commenced a westerly drift and then has drifted north of Iceland to the place of stranding; on the other hand, the period of drift is sufficiently long for the bottle to have entered the coastal current around Iceland and

gone with that current south and west of Iceland to the place of stranding. The former route must, however, be considered the most probable one, as it is a rare occurrence for bottles to follow the coastal current for such a long stretch without stranding. Cf. the Chapter on the coastal current around Iceland.

Of the remaining 7 bottles, 6 were launched south and southwest of Jan Mayen. The average rates of the bottles will appear from the following table:

Rate in miles per day	0—2	2—3	3—4	4—5	4—6
Number of bottles	1	1	2	2	1

The bottles indicate that rather considerable rates of current may prevail in these waters.

The 3 bottles launched north-east of Jan Mayen stranded in East Iceland after periods of drift of 293, 643 and 1490 days respectively, which corresponds to rates of between 2 and 0.2 miles per day, if they are considered to have drifted direct to the place of stranding. These rates are very small, so it is probable that the bottles in some way or other have been retained for some time in the Greenland Sea. For the two bottles with the longest periods of drift there is a possibility that they have been frozen in the ice for some time.

Finally, the 2 bottles launched in the most westerly positions remain to be mentioned. One of them was launched inside the Scoresby Sound and was recovered in West Iceland after a period of 606 days. This bottle has no doubt entered the East Greenland Current and been carried southward with it. In the latter part of the route the bottle must have followed the Irminger Current which runs northward along the west coast of Iceland, so the bottle must at some place in the South have passed from the East Greenland Current into the North-East Atlantic current system.

The last of the Iceland bottles was launched in 67°33′ N.—20°45′ W. and stranded in West Iceland after a period of 977 days. Also this bottle has probably come to the place of stranding from the South with the Irminger Current, and it would therefore be reasonable to presume that also this bottle has entered the East Greenland Polar Current and drifted along a route similar to but perhaps somewhat longer than that of the above-mentioned bottle.

Bottles from the Norwegian Sea to the Faroes.

As mentioned 27 bottles from the Norwegian Sea stranded in the Faroe Islands, of these 4 were launched close to the Faroes and give no information of interest. 8 bottles were launched close to the coast of East Iceland, 14 between North-East Iceland and Jan Mayen, and finally one off northern East Greenland.

The 8 bottles from East Iceland stranded after periods of drift of 97, 141, 208, 232, 251, 263, 265 and 821 days respectively. Except for the bottle having a period of drift of 141 days, all the bottles were launched simultaneously and on the same station. It will be seen that 5 of the bottles have had almost the same period of drift. Considering that the direct distance is only about 250 miles, the period of drift is exceedingly long. The most probable explanation of this fact is that as shown in the current chart in Fridtjof Nansen and Helland-Hansen: "The Norwegian Sea", there are a number of eddies over the ridge between Iceland and the Faroes and that at times drift-bottles may be retained for relatively long periods in these eddies.

Almost all the 14 bottles launched between East Iceland and Jan Mayen have had shorter periods of drift than the bottles from East Iceland. If we measure the distance along a route down along the east coast of Iceland and thence to the Faroe Islands and calculate the rates on the basis thereof, the following distribution will be obtained:

Rate in miles per day	1—2	2—4	4—6
Number of bottles	3	1	10

The rates are thus rather homogenous and show that at any rate at times there is a rather strong southerly current in these waters. As mentioned the same fact was shown by the bottles which from Jan Mayen drifted to Iceland.

Finally, the bottle which was launched in 72°53′ N.—20°36′ W., i. e. close to the east coast of Greenland and which drifted to the Faroe Islands shall be mentioned. The bottle was 1165 days en route and was launched so close to East Greenland that it must be taken for granted that it has commenced with a southward drift in the East Greenland Polar Current. It must then like the bottles launched in the westernmost positions have passed into the North-East Atlantic current system and been carried to the Faroes by that system. This route will be treated in detail in the analysis of the data from the Irminger Sea and the Denmark Strait.

Bottles drifting to the Shetlands and Orkneys.

Of the 17 bottles drifting to the Shetlands and the Orkneys, 6 were launched in the waters close around the Faroes, 9 between East Iceland and Jan Mayen, one north of Mevenklint and one in the Greenland Sea in 75°25′ N.—9°31 W.

The 6 bottles launched at the Faroes stranded after periods of drift of between 43 and 223 days. The widely differing periods must, like those for the bottles from the Faroe-Shetland Channel, probably be explained by the fact that the bottles have been retained for some time in eddies in the area of the Faroe-Shetland Channel. These bottles must thus have crossed the main stream through the Faroe-Shetland Channel.

In contradistinction to these bottles, those launched between East Iceland and Jan Mayen show rather homogenous periods of drift and rather great average rates. Only one bottle was not recovered until after 1366 days. The rates of the remainder will appear from the table:

Rate in miles per day	0—3	3—4	4—5	5—6	6—7
Number of bottles	0	1	2	4	1

The average rates of these bottles are almost identical with those of the bottles which from the same waters drift to East Iceland and the Faroes, so it must be presumed that they have rather quickly drifted across the Faroe-Shetland Channel without having been retained in eddies there for any length of time.

Finally, we have left only the bottles launched in the westernmost and northernmost positions. The long periods of drift are common to these 2 bottles, namely 504 days for the southernmost one and 1145 for the northernmost. These periods of drift indicate that both

bottles have entered the East Greenland Current and been carried southward, whereafter the bottles have drifted by approximately the same route as that described for the westernmost Faroe bottle.

Bottles stranding in Western Greenland.

Two bottles have from the Greenland Sea drifted to Western Greenland. The faster of them was launched in 77°12′ N.—16°00′ W. and was recovered in the Godthaab Firth after a period of 387 days. It has thus drifted 1750 miles with an average rate of 4.5 miles per day. The second bottle was launched in the mouth of Scoresby Sound and was recovered after 1100 days between Godthaab and the Sukkertoppen. The place of launching and the long period of drift make it probable that the bottle has been ice-bound for one or perhaps even two years before it has left the sound and has entered the East Greenland Polar Current. Both bottles must south of Cape Farewell have turned north-westwards and then have followed the West Greenland Current to the places of stranding.

It must be noted that the rate of 4.5 miles per day is the average rate for a period of more than a year. It is probable that the East Greenland Current is strongest in the summer when the smelting of the ice is most rapid, but the high average seems to indicate that the rate is not quite insignificant at any time of the year.

Finally, mention shall be made of a bottle which from the Greenland Sea drifted to the Hebrides off Western Scotland. The bottles was launched in 77°42′ N.—14°30′ W., in other words, not far from the bottle which stranded in West Greenland after a period of 387 days. The period of drift of the bottle was 948 days and it has no doubt followed the same route as the Greenland bottle until Cape Farewell. Possibly, like the Greenland bottle it has drifted into the southern part of the Davis Strait. It must then have turned westward and have entered the Labrador Current and been carried by that into the North-East Atlantic current system. In our analysis of the Denmark Strait we shall make a detailed examination of these routes.

If we are to summarize in brief the information about current conditions in the Norwegian Sea and the Greenland Sea that may be derived from the drift-bottles dealt with in this part of the work, it must be that from the waters around Jan Mayen there is a rather strong southward current, the socalled East Icelandic Current, which passes east of Iceland and down into the waters north of the Faroes. The most frequent period of drift for bottles in this area is 4—5 miles per day. The great number of bottles drifting to Norway shows that the current north of the Faroes must turn eastward and then along the coast of Norway mingle with the Atlantic water which through the Faroe-Shetland Channel and perhaps also north of the Faroes streams into the Norwegian Sea. The period of drift from Jan Mayen to the Faroes is about 100 days, so a somewhat longer period of drift might be expected for the Norway bottles launched south of Jan Mayen than for those launched north of the Faroes. When no such difference has been found, it may be due to the fact that the data from the two areas originate from different years with different rates of current, or perhaps that the bottles from the northernmost area drift by a more northerly and shorter route than the bottles launched in more southerly positions.

The bottles launched over the ridge between the Faroes and Iceland and drifting to

the Faroes have a considerably longer period of drift than the bottles launched north of the ridge. This indicates that over the ridge proper there will frequently be eddies in which the bottles may be retained for considerable periods of time.

The western part of the Norwegian Sea proves to be considerably different from the waters between East Iceland and Jan Mayen. The Norway bottles no longer dominate, and most bottles do not strand until after long periods of drift. The explanation lies as mentioned in the fact that the water masses from this area stream down through the Denmark Strait as the East Greenland Polar Current which carries the bottles southwards into the Nort-East Atlantic current system.

Chapter 3.

The Coastal Current around Iceland.

Previous drift-bottle experiments prove that the coastal water around Iceland moves in a clockwise direction around the country. This is confirmed by an examination of all the data at present available, as only a small number of bottles have been recovered in positions corresponding to an anti-clockwise movement, and in such cases the positions of recovery are usually only a short distance (less than 50 miles) from the places of launching and the periods of drift are also short.

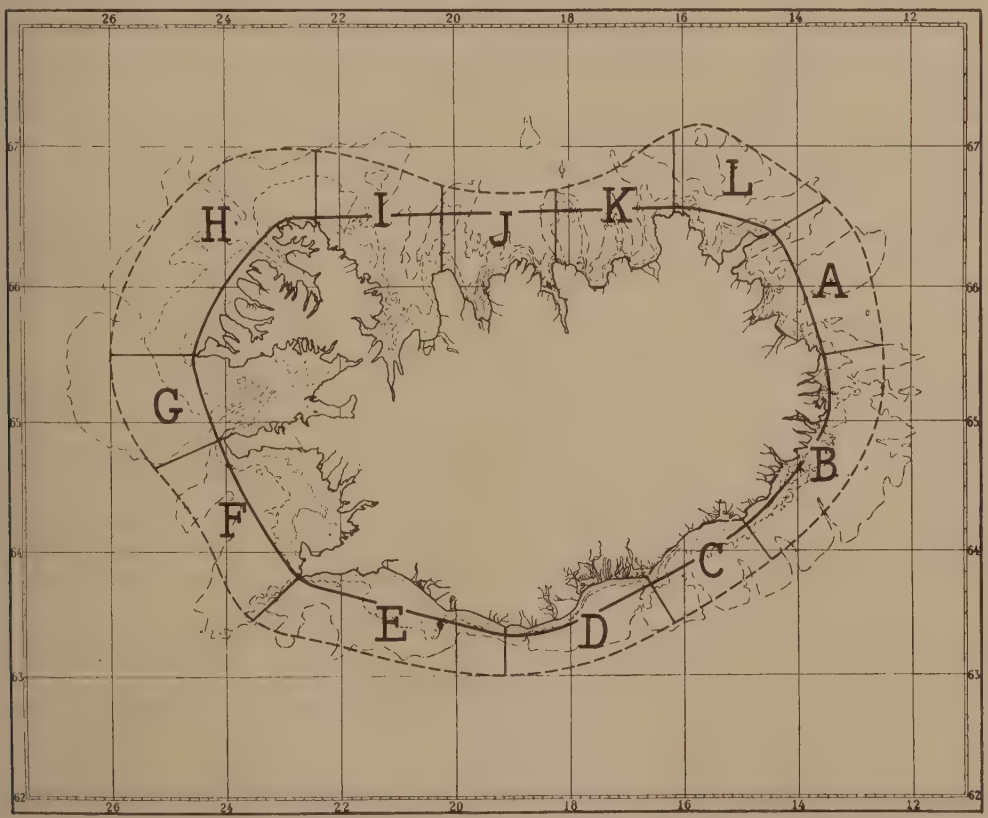


Fig. 6. Boundary line of coastal area and track (full drawn) along which drift distances have been measured.

It is impossible on the basis of the present data to determine how far from the coast the coastal current extends. By far the greater part of the bottles launched in the waters around Iceland have been launched within the 200-metre curve, and this curve is generally considered the limit of the coastal area. However, at many places around Iceland this curve is so irregular that in this connection it would be inexpedient to use it as a limit. For the coastal area a regular curve has therefore been plotted as a limit, a curve which roughly follows the 200-metre curve, but which eliminates its many irregularities. The course of the limit will appear from Fig. 6. Close to the coast another curve has been plotted, encasing the contours of the coastline, and along this curve the distance of drift of the bottles has been measured, the launching and recovery positions of the bottles having been projected down on this curve.

Of the bottles launched in the coastal area a total of 410 have been recovered and of these 258 were recovered in or off Iceland. If these bottles are grouped according to distance of drift, the following distribution will be obtained, the positive distance being reckoned clockwise (see Table 3).

It will be seen that 150 of the bottles or about 58 % do not go beyond a zone of 50 miles on either side of the place of launching before they drift ashore. 19 bottles were found from 50 to 300 miles in an anti-clockwise direction from the place of launching, and only 89 bottles were stranded at distances between 50 and 650 miles in a clockwise direction from the places of launching.

If we consider a large number of bottles (A_0) launched in the coastal current and we further consider that the tendency of all bottles to drift ashore is equal at all places along the coast, we have for the number of bottles (dA) drifting ashore along the coastline dx at distance d from the place of launching

$$-dA = k \cdot A \cdot dx,$$

in which k is a factor of proportionality. By integration we get

$$A = A_0 e^{-kx},$$

from which will appear that the number of drifting bottles will decrease exponentially with the distance from the place of launching. If we consider the coast divided into equal sections of length l, the formula will show that the ratio between the number of bottles landed in two consecutive sections will be e^{kl}, or in other words a constant.

Table 3.

Distance	Number of bottles	Number of bottles with a period of drift of less than 190 days
—250 —300	1	0
—200 —250	1	0
—150 —200	7	0
—100 —150	1	0
— 50 —100	9	0
— 50 50	150	149
50 100	41	35
100 150	19	17
150 200	11	9
200 250	7	2
250 300	3	3
300 350	2	1
350 400	1	0
400 450	0	0
450 500	2	1
500 550	1	0
550 600	1	0
600 650	1	0
650 700	0	0
700 770	0	0
	258	217

A glance at Table 3 will show that when we disregard the zone of launching, the ratio between bottles landing in two consecutive sections will be approximately 2:1 for the zones in which the number of bottles is greatest (41—19—11—7—3).

The above remarks apply only to bottles following the coastal current until the point of stranding. However, not all bottles launched in the coastal current and stranding in Iceland will have followed the coastal current throughout their drift. As mentioned elsewhere, a not inconsiderable number of bottles may with great certainty be ascertained to have left the coastal area of Iceland at the north-west country and to have drifted into the coastal area again at the south coast or west coast after having made a circuit in the Irminger Sea. The 19 bottles shown in Table 3 as having drifted distances between —50 and —300 miles (with perhaps a single exception) all belong to this category. Common to all of them are periods of drift of upwards of 190 days.

It must be considered that also at other places bottles may leave the coastal current and nevertheless return and strand in Iceland. It is difficult to distinguish these bottles; they are characterized by an unusually long period of drift, but a long period will also arise if a bottle has been lying undiscovered on the beach. If we leave out of consideration all bottles having a period of drift of upwards of 190 days, 217 bottles remain, the distribution of which within the different distance intervals is shown in Table 3.

The numbers of stranded bottles in the intervals 50—100, 100—150 and 150—200 miles are respectively 35—17—9, so that the ratio between the numbers stranded in two consecutive intervals after the reduction made is almost exactly 2:1, which gives $k = 0.6931$, when 50 miles is the unit of distance.

This is, of course, only an approximate average value, in which no regard has been paid to the fact that the bottles have been launched at different distances from the coast, and that the tendency of the bottles to drift ashore is not equal for all stretches of the coastline; it affords, however, sufficient basis for a judgment as to whether a bottle may be imagined to complete an entire circuit in the coastal current. The total distance x_t being 15.4×50 miles the probability thereof will be $\frac{A_0}{A} = e^{-kx_t} = e^{-10.7} = \frac{1}{44250}$. In considering the available data which comprise only 258 bottles we may thus entirely disregard the possibility of a bottle completing a full circuit in the coastal current around Iceland.

Rate of the Coastal Current.

The two serious sources of error attaching to the determination of the rates of current by means of drift-bottles, namely the lack of knowledge of the track followed by the bottle and the exact period of drift, may to some extent be eliminated in the treatment of the available data.

It is impossible by means of drift-bottle experiments to elucidate the course of the coastal current in detail; we must be content if in this manner we can find out how far a floating body will move on an average along the idealized coastline plotted in the chart in Fig. 6. We may thus consider the tracks of the bottles a known factor, if we disregard the bottles which to an appreciable extent leave the coastal area. These bottles will be practically entirely eliminated if we disregard bottles with a period of drift of more than 190 days.

It will be more difficult to eliminate the effect of the time during which the bottles are lying undiscovered on the beach after stranding. The error of the computed rate will be the

greater the longer the period of waiting is in relation to the unknown period of drift. As on an average the period of drift must increase proportionally with the distance, the data may in the computation of the average rate of current be improved statistically if the bottles which have not drifted 50 miles or more along the coast are disregarded.

As the data most suitable for a calculation of the average rate of the coastal current,

Fig. 7. Synopsis of the drift bottle records inside the coastal area. Dividends: No. of bottles launched in the section and having drifted more than 50 miles in the coastal current. Divisors: Total No. of bottles launched in the section and recovered.

those of 68 bottles remain. These bottles are distributed along the coastal area as shown in Fig. 7. In each of the fields indicated by heavy boundary lines, the dividend indicates the number of bottles that have been launched in the field and which have drifted more than 50 miles along the coast. The divisor indicates the total number of recovered bottles launched within the field.

If we compute the rate of drift of each of these bottles by dividing the number of days from the launching to the recovery into the distance measured along the curve plotted in Fig. 6, we will obtain rates ranging between 0.5 and 13.8 miles per day and averaging 3.3 miles per day. The different rates are distributed as to frequency as follows:

Table 4.

Rate	0 —0.9	1.0 —1.9	2.0 —2.9	3.0 —3.9	4.0 —4.9	5.0 —5.9	6.0 —6.9	7.0 —7.9	8.0 —8.9	9.0 —9.9	10.0 —10.9	11.0 —11 9	12.0 —12.9	13.0 —13.9
Number of Bottles	8	14	12	13	10	1	4	2	1	0	0	0	2	1

It will be seen that no single rate is predominant, but that the five first rate intervals are almost equally represented and that together they take up 57 of the 68 bottles.

If we supposed the rate of the coastal current to be very constant both as regards time and place, the number of bottles might be expected to show a maximum at this rate, or rather at a slightly lower rate, in view of the waiting period of the bottles on the beach. The frequency distribution found must therefore be construed to mean that the rate of the coastal current is very variable.

As the rate of the coastal current cannot be assumed to be the same along all sections of the coast, the coast has been divided into 12 zones, A—L (see Fig. 6), and Table 5 shows the rates of drift found within each zone, the rate of drift of a bottle which has drifted through several zones being given for each zone.

Table 5.

		Mean
A	3.1—2.5—1.9—1.0—2.3—0.7—3.4—5.0—4.0—2.5—6.1—4.1—4.4—4.0—4.1	3.3
B	7.7—3.7—3.4—1.5—2.8—13.8—3.3—3.4—1.6—3.1—2.5—1.0—2.3—0.7—4.0—4.1	3.7
C	7.7—3.7—3.4—1.5—1.5—13.8—3.3—3.4—1.6—3.1—4.0—4.1	4.3
D	7.3—4.6—0.5—7.7—3.7—3.4—1.5—2.7—1.5—13.8—3.3—3.4—1.6—3.1—4.1	4.1
E	7.3—4.6—4.1—4.8—6.3—3.3—3.6—6.2—2.6—12.6—3.6—12.6—4.2—1.5—3.4 3.1—0.9—3.2—1.9—0.6—2.7—3.2—1.9—3.7—1.9—1.5—1.5—2.8—8.1—1.6	4.0
F	7.3—3.1—0.9—3.2—0.6—2.7—3.2—1.9—3.7—1.5—1.5—2.8—8.1—1.6	3.0
G	7.3—3.1—1.9—1.0	3.3
H	1.9—1.0—2.0—3.0—0.7—0.9—0.9	1.5
I	2.0—3.0	2.5
J	2.0—4.1—2.0—3.0—6.2—1.2—8.0	3.8
K	2.0—4.1—2.5—1.4—4.1—2.5—2.0—1.2	2.5
L	3.4—5.0—4.0—2.5—4.3—6.1—4.1—4.1—4.0—4.1	4.2
	Average...	3.35

It will be seen that the average rate of drift is about 3—4 miles per day except for zones H, I and K in which it is somewhat lower. The data from the different zones are, however, so few that a change of the averages may occur, if more data were added. This, of course, applies particularly to the zones I and G. The variation in average rate from zone to zone shows such features that it may be presumed that the rate of the coastal current is really different along the various coastal areas. If we collect the zones in larger areas we will find the distribution of frequencies and average current rates shown in Table 6.

It will be seen that the frequency distribution of the rates shows a maximum within each section of the coast and that the location of the maximum and the average rate are different for the four coast sections. The maximum rate of current is found at the south and east coasts and the minimum at the north and west coasts.

The computed current rates are, of course, somewhat smaller than the actual rates,

Table 6.

Area	L+A+B	C+D+E	F+G	H+I+J+K
Naut. Miles/Day	East Coast	South Coast	West Coast	North Coast
0.0— 0.9	3	3	2	3
1.0— 1.9	4	13	6	5
2.0— 2.9	7	4	2	8
3.0— 3.9	8	18	5	3
4.0— 4.9	13	8	0	3
5.0— 5.9	2	0	0	0
6.0— 6.9	2	2	0	1
7.0— 7.9	1	4	2	0
8.0— 8.9	0	1	1	1
9.0— 9.9	0	0	0	0
10.0—10.9	0	0	0	0
11.0—11.9	0	0	0	0
12.0—12.9	0	2	0	0
13.0—13.9	1	2	0	0
Average rate...	3.6	4.1	3.1	2.6

the unknown waiting period being included in the period of drift. Concerning the average of the unknown waiting period, information may be derived as follows:

We suppose the data divided into two groups according to distance of drift, so that Group I consists of n_1 bottles which on an average have drifted the distance a_1. Time from launching to recovery: d_1, waiting period on the beach: l. For Group II corresponding designations are used, but the actual rate of drift: v and the waiting period: l are supposed to be identical for both groups. We then have:

$$n_1 \cdot a_1 = v \cdot n_1 \ (d_1 - l)$$
$$n_2 \cdot a_2 = v \cdot n_2 \ (d_2 - l)$$

whence

$$l = \frac{a_2 \cdot d_1 - a_1 \cdot d_2}{a_2 - a_1} \qquad v = \frac{a_2 - a_1}{d_2 - d_1}.$$

If we divide the 68 bottles which have drifted at least 50 miles in less than 190 days into two equal groups according to distance of drift, we find

$$a_1 = 74 \text{ naut. miles} \qquad a_2 = 168 \text{ naut. miles}$$
$$d_1 = 44 \text{ days} \qquad d_2 = 62 \text{ days}$$

which introduced in the above formula will give:

$$l = 30 \text{ days}$$
$$v = 5.2 \text{ miles per day.}$$

This waiting period and as a consequence also the rate of drift seems rather high, and it must be borne in mind that the mode of computation used is based on the assumption that the number of observations is high in proportion to the limits within which the waiting period may vary, so that it may be taken for granted that the average waiting period for any one half

of the bottles will be identical with that for the other half. The available data comprising 68 bottles do not seem adequate to fulfil this requirement fully. This fact will emerge, if the data be divided into 3 parts instead of two, as then by combining 2 and 2 of the three groups, the waiting periods 2, 19 and 39 days will result.

Another means for the determination of the average waiting period of bottles will be found in the bottles which have drifted only a short distance before stranding. A total of 137 bottles stranded before they had drifted a distance of 50 miles. The average distance was 18.7 miles and the bottles were found on average 20 days after their launching. As the waiting time cannot be supposed to be dependent upon the distance of drift, the term of 20 days may be considered an upper limit for the average period of waiting. This period will, of course, differ for inhabited and uninhabited coastlines and must be presumed to vary considerably within each of the 12 coastal sections A—L, but on the basis of the data available, it will be impossible to obtain further information in this respect.

Along the coastal section E, i. e. between Dyrhólaey and Reykjanes especially many bottles have been launched and recovered, namely 57. On an average these bottles were found 16 days after launching, whereas the corresponding average for the remainder is 23 days. From these figures it will be possible to derive the average waiting periods when the average distance and the average rate of drift are known.

For Section E we find the average distance 32 miles.

For the remaining sections we find the average distance 10 miles.

As an approximate value of the average rate of drift we use the figures from Table 5. We will then have a rate of drift in Section E of 4.0 miles per day and for the remaining sections of 3.3 miles per day. The average waiting period for Section E will thus be:

$$16 - \frac{32}{4.0} \text{ days} = 8 \text{ days, and for the remaining sections:}$$

$$23 - \frac{10}{3.3} \text{ days} = 20 \text{ days.}$$

We shall now attempt a renewed discussion of the 68 drift bottles that have drifted a distance of not less than 50 miles in less than 190 days, grouping them according to coastal sections in the manner of Table 5, and within each section taking sums of distances and days. The following figures will then be obtained:

Table 7.

Coastal section	A	B	C	D	E	F	G	H	I	J	K	L	Average, entire coast
Sum of distances	2197	2854	2619	2975	3851	1984	1009	1008	436	834	842	1390	
Sum of days	791	1057	884	1107	1463	906	365	731	184	393	370	348	
Number of Bottles....	15	16	12	15	30	14	4	7	2	7	8	10	
Average wait. period..	300	320	240	300	240	280	80	140	40	140	160	200	
Corrected drift period..	491	737	644	807	1223	626	285	591	144	253	210	148	
Corrected rate of drift..	4.7	3.9	4.1	3.7	3.1	3.2	3.5	1.7	3.0	3.3	4.0	9.3	3.96

The corrected rates of drift found vary rather evenly from zone to zone except for Zone L (Rifstangi—Langanes) in which we find a rate of drift of 9.3 miles per day, which is about twice

that of the neighbouring zones and also of that of the same zone when no regard is paid to the waiting period.

The less the data, the greater the inaccuracy of correction for the waiting period. It cannot therefore be considered certain that the variation of the corrected rates from zone to zone reflect actual conditions. On an average for the whole coastline the rate of 3.96 miles per day is obtained, whereas the average rate uncorrected amounts to 3.35 miles per day. The corrected average rate is thus 18 % higher than the uncorrected one. If the average rates for the individual zones as shown by Table 5 are increased by 18 %, the following figures will result (upper line):

Table 8.

	A	B	C	D	E	F	G	H	I	J	K	L
Uncorrected + 18 %	3.9	4.4	5.1	4.8	4.7	3.5	3.9	1.8	2.9	4.5	3.0	5.0
Corrected	4.7	3.9	4.1	3.7	3.1	3.2	3.5	1.7	3.0	3.3	4.0	9.3
Miles per day, average	4.3	4.1	4.6	4.2	3.9	3.4	3.7	1.8	3.0	3.9	3.5	7.1

The best obtainable figures for the rate of current in the different sections will be those given in the last line of the table, which have been obtained through 2 sets of mean values. On account of the scarcity of the data, the more certain procedure would be to combine the mean values for the individual zones into mean values for larger parts of the coast. It would be natural to use the same coastal areas as those given in Table 6, and we will then obtain the following averages for the rate of current:

Table 9.

East coast from Rifstangi to Vestrahorn (L + A + B)	5.2 miles per day
South coast from Vestrahorn to Reykjanes (C + D + E)	4.2 — —
West coast from Reykjanes to Látrabjarg (F + G)	3.5 — —
North coast from Látrabjarg to Rifstangi (H + I + J + K)	3.1 — —
Average	4.0 miles per day

If we compare these averages with the figures of Table 6, it will be seen that the decrease of the rate of current from the east coast via the south coast and the west coast to the north coast is reflected in the position of the frequency maximum.

Variation of Rate of Current.

As mentioned in the above, the average rates of current found refer to an idealized coastal current following the curve enveloping the coast contours. No attempt has been made to find out the extent to which the coastal current follows the contour of the coast. If the bottles for instance in Faxaflói follow the coast from Reykjanes to Snæfellsnes, the distance of drift will be about 70 % greater and the actual rate of the coastal current also 70 % greater than the calculated value. As, however, we do not know the actual tracks of the bottles and as the computed rates of current can be used only as a basis for a judgment of the distance of drift of a floating body for a certain number of days, or the period required for a floating body to drift a given longer distance, it will be simpler to calculate with an idealized coastal current.

The rate of the coastal current varies within rather wide limits. Of the 258 bottles stranded on Iceland, 18 or 7 % have been recovered "behind" the place of launching, thus corresponding to a negative rate of current. The maximum distance between the place of launching and the place of recovery was 42 miles. The maximum negative rate of current ascertained was 4.0 miles per day. The following table shows distances of drift, number of days and rate of drift of the 7 fastest bottles. The remaining 11 bottles have rates of drift of less than 1 mile per day.

Table 10.

Coastal section	Distance	Days	Rate
K	—12	3	—4.0 miles per day
C	—30	8	—3.8 — - -
I	—30	9	—3.3 — -
H	—40	15	—2.7 — - -
D	—35	16	—2.2 -
C	—21	15	—1.4 — - -
A	—42	39	—1.1 — - -

The instability of the back current will appear from the Table, as it will be seen that the greater the rate of current, the shorter the time and the distance through which it has been ascertained.

The back current has been observed on the north, east and south coasts and will probably also be found to exist on the west coast.

The maximum positive rates of current ascertained are:

East Coast	13.8	miles	per	day
South Coast	13.8	—	-	-
West Coast	12.5	—	-	- [1]
North Coast	9.0	-	-	-

Bottles recovered while adrift.

A small number of bottles were recovered while adrift in the Icelandic coastal area. The places of launching and recovery together with the rate of drift have been plotted in the chart in Fig. 8. It will be seen that the rates of drift found come within the limits for the rates of drift computed on the basis of the stranded bottles, but otherwise it is impossible to deduce general rules on the basis of these sparse data, which only confirm the above statement on the variable character of the coastal current. Especially characteristic in this respect are the three bottles launched north of Rifstangi, two of which drifted directly counter to the average set of current with considerable speed, whereas the third one drifted almost across the general direction of current but at a slow speed.

The Tendency of the Drift-Bottles to leave the Coastal Area.

In the chart, Fig. 9, the coastal area is divided into a number of fields bounded by the coastline, the boundary of the coastal area and parallels of longitude and latitude. In the fields

[1]) Bottles found adrift 2 days after launching.

fractions are given, in which the divisor gives the number of recovered bottles launched within the field, whereas the dividend shows the number of bottles that have left the coastal area.

It will appear from the chart that more than one-half of the bottles launched in the coastal area along the east coast from Rifstangi to Ingolfshøfde leave the coastal current. From the areas between 64° and 65° N. especially many bottles drift away, namely about 90 %.

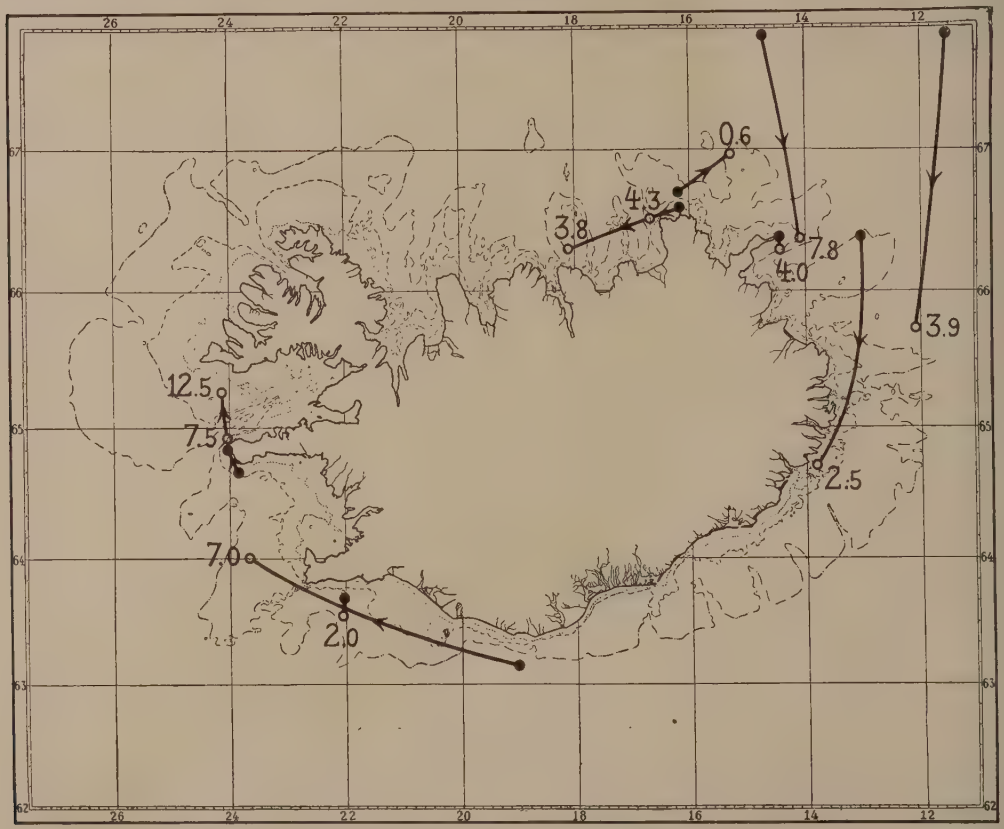


Fig. 8. Bottles recovered adrift. ●: Position of launching. ○: Position of recovery. The rate of drift in naut. miles per day is indicated at the position of recovery.

This is compatible with the fact that in the neighbourhood of Vestrahorn a sharply marked boundary will frequently be found between water of polar characteristics and water with Atlantic characteristics, probably formed because the coastal current at this place as part of the East-Icelandic Current leaves the coastal area on its way southwards.

The anti-cyclonal current around Iceland should thus at this place have a discontinuity line not passable by floating bodies. However, among the 128 recovered bottles launched along the stretch from Vestrahorn to Langanes, 10 bottles have stranded on the south coast or west coast after the lapse of from 14 to 149 days, corresponding to rates of between 1.5 and 13.8 miles per day. It must be presumed that these bottles have not to an appreciable extent left the coastal area, so that in these cases there has been a continuous stream along the coast from the east coast to the south coast.

Besides these 10 bottles which must be presumed not to have departed appreciably from the coastal area, there are 11 bottles launched in the same area and recovered on the south coast after the lapse of 272 to 1106 days. Some of these may not have left the coastal area, but may for a long time have been lying undiscovered on the very sparsely populated coast between Hornafjörður and Dyrhólaey, but as far as the majority is concerned, it must

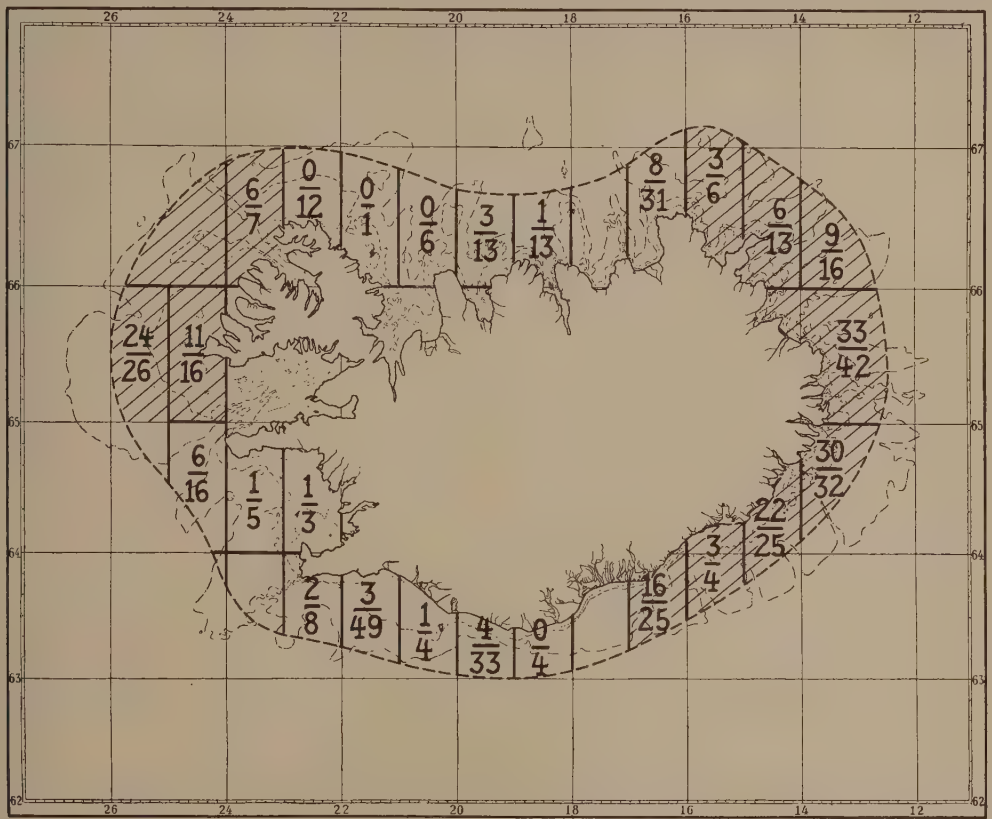


Fig. 9. Tendency of the bottles to leave the coastal area. Dividends: No. of bottles launched in the coastal area and recovered elsewhere. Divisors: Total No. of bottles launched in the section and recovered.

be presumed that they have departed from the coastal area with the East-Icelandic Current off Vestrahorn and later have got into the Atlantic Current and been carried back to Iceland by that current.

These data lead us to assume that the probability of a bottle passing the critical point off Vestrahorn with the coastal current may be put at $^1/_{10}$.

Another area in which the bottles likewise show a pronounced tendency to leave the coastal area is to be found off the north-west country. The tendency is also in this area very great, especially for the bottles launched at the greatest distances from the coast. Off Látrabjarg we thus find that about 70 % of the bottles launched between 24° and 25° W. drift away, whereas about 90 % of those launched between 25° and 26° W. drift away. This is due to a divergence of current, the majority of the water masses streaming northward along the west

coast of Iceland diverging out into the Denmark Strait at the Iceland-Greenland ridge, whereas only a smaller part continues along the coast. There is nothing to indicate an established position of the line of divergence, so that it might be taken that the water inside the line would continue along the coast while that outside diverges into the Denmark Strait. The fact must be presumed to be that the water under the influence of weather conditions at times all moves

Fig. 10. Tendency of the bottles to strand before they have drifted 50 miles. Dividends: No. of bottles launched in the section and having drifted less than 50 miles before stranding. Divisors: Total No. of bottles launched in the section and recovered.

into the Denmark Strait, whereas at other times a considerable proportion passes the Horn and continues along the north coast of Iceland.

Along the north coast and the south coast the tendency of bottles to leave the coastal area is but slight. The effect of the rotation of the Earth will along these coasts tend to keep the current in against the coast.

The chart in Fig. 10 gives a summary of the tendency of the bottles to strand before they have drifted 50 miles. The large percentage of stranding are found in the northern and southern parts of the country, whereas the stranding tendency is slight along the east coast and off the north-west coast.

Chapter 4.

The Area South and West of Iceland.

In this part the entire area west of 10° W. and south of 65° N. and the Denmark Strait area west of 22° W. and south of 67° N. will be discussed. Except for 21 drift-bottles launched by the "Newfoundland Fishery Research Laboratory", all the bottles forming part of these experiments were launched by Danish ships in the years 1892, 98, 99, 1900, 01, 02, 05, 06, 08, 16, 28, 29, 31, 32, 33, 34, 35, 38 and 39.

The most complete data in this area are to be found in the waters south-east of Iceland down to 60° N. and along the west coast of Iceland, also in the Denmark Strait and along the east coast of Greenland the data are fairly good, while in the Irminger Sea they are extremely sparse. In the waters south of 60° N. the data are relatively sparse except in the near proximity of Rockall Bank.

The data from this area and especially from its western part are especially characterized by the great numbers of bottles stranding after long periods of drift, and by the many widely separated places of stranding. From this area bottles have been recovered on the coasts of Iceland, Western Greenland, Labrador, Newfoundland, Ireland, Scotland, on the Orkneys, Shetlands and Faroes, on the coasts of Norway and on North Sea coasts.

The main features of the currents in these waters are outlined in Chapter 1, so far as it was possible to elucidate them solely on the basis of a consideration of places of launching and places of recovery. In this part it is intended to make a more detailed examination, the periods of drift being included in the consideration.

The current chart most frequently used for the waters south and south-west of Iceland was drawn up by C. Ryder on the basis of drift-bottle experiments. According to this current chart the greater part of the waters south of Iceland should be filled up by a branch of the North-East Atlantic current system streaming west of the Faroes and then along the south coast of Iceland in a westerly direction.

This current chart is hardly compatible with the results of the statistics in Part 1 which proved that 76 % of the bottles from Area C drifted to Norway. There is, however, a possibility that the bottles have started with a westerly drift and then after a long circuitous route have got into the eastward current towards Norway. We must now expect to find rather considerable differences between the periods of drift of the bottles commencing with a westward drift and of those drifting directly eastwards. This applies not only to the bottles stranding along the Norwegian coast, but to all bottles stranding on the coasts of the north-eastern Atlantic. In the following we will therefore by means of statistics of the periods of drift endeavour to find the

boundary between the areas with preponderant eastward drift and those with preponderant westward drift.

We will now first consider the distribution of the periods of drift of bottles at the various stranding places.

Period of Drift of the Norway Bottles.

As mentioned in Chapter 1, the Norway bottles dominate as to number for great parts of the area, and their periods of drift will now first be discussed, the waters south and west of Iceland being divided into several smaller areas.

For the first area, namely that between 10° and 15° W. and between 60° and 65° N. the distribution of the periods of drift will appear from Figs. 11 a and 11 b, the same grouping with overlapping intervals being used as in the discussion of the Norway bottles from the Faroe-Shetland Channel and from the Norwegian Sea.

Fig. 11 a shows the curves of distribution partly for bottles stranded in $N_2 + N_3$ and partly for bottles stranded in $N_4 + N_5$. For both stranding areas rather smooth curves of distribution are obtained with maxima of 200 and about 325 days of drift respectively, so the most frequent periods of drift will be only slightly longer for this area than for the Faroe-Shetland Channel and the waters north of the Faroes. There is no indication of two maxima

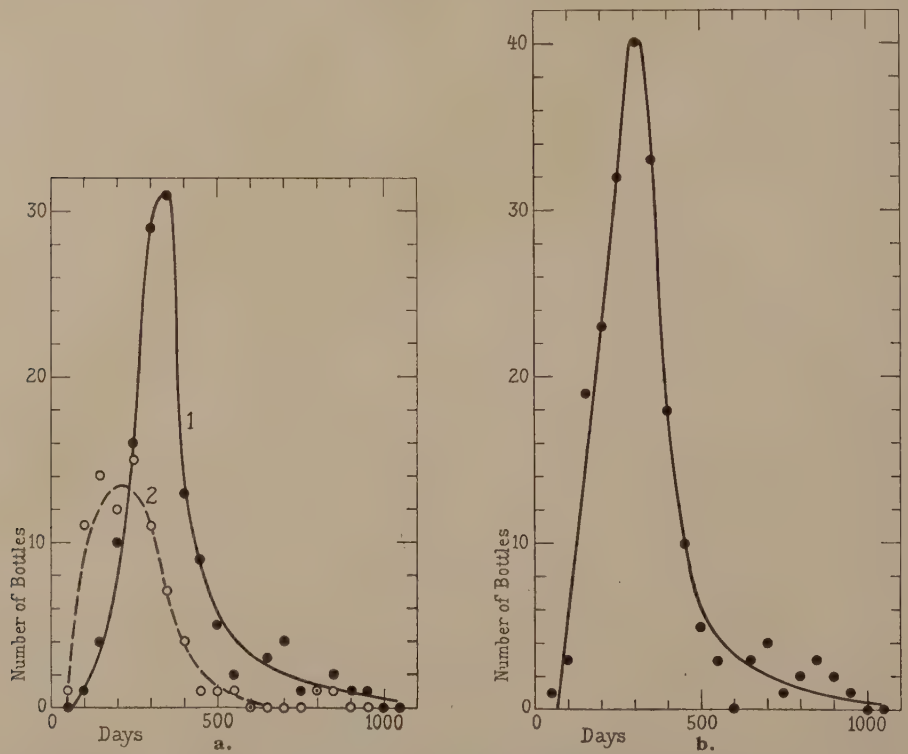


Fig. 11. Frequency distribution of drift time for bottles launched between 10° W.—15° W. and 60° N.—65° N.
a. o - - - o: Bottles recovered on $N_2 + N_3$. ●——●: Bottles recovered on $N_4 + N_5$.
b. Bottles recovered on $N_2 + N_3 + N_4 + N_5$

in the curve for bottles stranded in $N_4 + N_5$, as was found in the corresponding curve for the Faroe-Shetland Channel.

In this area the data are sufficient to permit separate investigations as regards bottles drifting to Southern Norway and bottles drifting to Northern Norway. In other parts of the waters south and west of Iceland the data are, however, so sparse that it is necessary to take all the Norway bottles together in order to obtain adequate data for reasonably certain curves of distribution. In order to allow a comparison between the curves of distribution for the various areas, Fig. 11 b has been drawn showing the curve of distribution of all Norway bottles, 106 in all, from the area under discussion. It will be seen that the curve has a rather pronounced maximum at about 300 days, and that on the whole the curve does not differ much from the curve of distribution for the bottles to $N_4 + N_5$ alone.

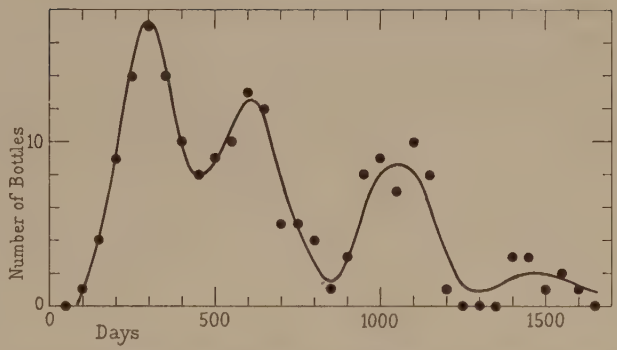


Fig. 12. Frequency distribution of drift time for bottles launched between 15° W.—42° W. and 60° N.—67° N. and recovered on the coast of Norway.

In the same way we find (Fig. 12) the curve of distribution for all Norway bottles launched in the area between 15° and 42° W. and 60° and 67° N., and (Fig. 13) the curve for all Norway bottles launched between 18° and 42° W. and 60° and 67° N. The data on which Fig. 12 is based comprise 94 bottles and those of Fig. 13 of 51 bottles.

Fig. 12 shows a distribution of periods of drift quite different from that of Fig. 11 b, as in Fig. 12 we get three maxima. The first maximum, which predominates, lies at 300 days, in other words at the same level as that of Fig. 11 b, whereas the two other maxima are at 600 days and 1050 days respectively.

If next we consider Fig. 13, which shows the distribution for the same area as Fig. 12, except for the waters between 15° and 18° W., the same three maxima as in Fig. 12 will appear, only from being the dominating maximum the first one has almost entirely disappeared, whereas the other two maxima have been only slightly diminished.

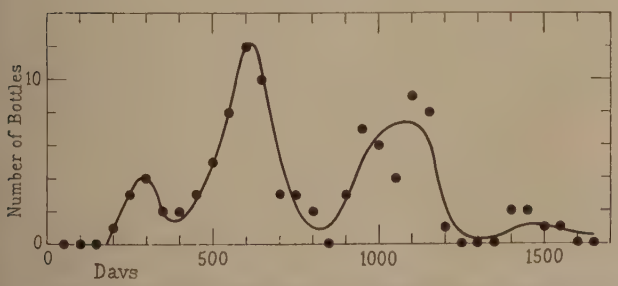


Fig. 13. Frequency distribution of drift time for bottles launched between 18° W.—42° W. and 60° N.—67° N. and recovered on the coast of Norway.

It thus appears that the Norway bottles may be divided into three groups according to periods of drift. The first group comprises the bottles with the shortest periods of drift and includes the bottles launched in the easternmost positions. As the periods of drift of these bottles are almost the same as those of bottles drifting to Norway from the Faroe-Shetland Channel, it must be taken for granted that they have drifted direct to the places of stranding, the

northern most ones to the north of the Faroes and the southernmost ones perhaps through the Faroe-Shetland Channel (Cf. Chapter 1, page 10).

The two other groups formed by the westernmost bottles must consist of the bottles which commenced with a westerly drift, but the course of their tracks cannot be seen until a sufficient basis for a comparison has been obtained through an investigation of bottles with other places of stranding.

It will be seen that the three maxima are rather broad, so there is no especially well-defined period of drift for the Norway bottles. This was, of course, to be expected, as both the distances between the places of launching and those between the places of stranding along the coast of Norway are so great as to give rise to a rather considerable spread in the periods of drift. The reason why it is possible to take all the Norway bottles from a rather extensive area under one heading and thus obtain data for a statistical treatment is, in the first place, that the distribution of places of stranding is almost uniform within the three areas, and, in the second place, that the spread in periods of drift will not be great in proportion to the difference between the periods of drift of the different groups.

Periods of Drift of the Iceland Bottles.

After this preliminary discussion of the Norway bottles, we will now consider the bottles recovered on the coast of Iceland, the short-term bottles discussed in the paragraph on the coastal current around Iceland being disregarded.

The area from which most bottles are found in Iceland is that covering the waters west of Iceland. The Iceland bottles, which were launched between 22° and 29° W. and 62° and 67° N., will be discussed in the same manner as the Norway bottles, the curve of distribution of their periods of drift being ascertained using a grouping in intervals of 50 days (see Fig. 14). This curve shows a very pronounced maximum at a period of drift of about 225 days.

All the bottles have stranded in South and West Iceland, i. e. in the neighbourhood of the places of launching, so the most reasonable assumption as to their track would be that they had drifted direct to the place of stranding. This hypothetical route would, however, in the first place entail the fact that many of the bottles must have drifted against the coastal current around Iceland, and, in the second place, it cannot by any means explain the homogeneity in the periods of drift. Next, it might be imagined that the bottles had drifted with the coastal current around Iceland, but also this hypothesis must be rejected (Cf. page 33).

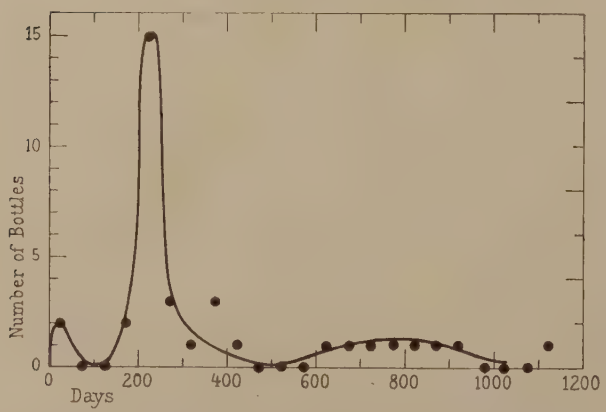


Fig. 14. Frequency distribution of drift time for bottles launched between 24° W.—29° W. and 62° N.—67° N. and recovered on the west coast of Iceland.

The only possibility remaining is that the bottles and thus also the water masses direct to the West of Northern Iceland drift to the North-West and then follow some circuit in the Irminger Sea, so that the bottles return to the place of stranding from the South. If this track is the correct one, there should thus in the Denmark Strait and the

Irminger Sea be a large circuit with a period of about 225 days. We shall revert to the limits of this circuit at a later stage.

It would be reasonable to suppose that the Norway bottles forming the last two groups of Fig. 12 and 13, or to all intents and purposes, the bottles launched west of 18° W. have commenced with a westward drift, and that thereafter they have followed for some period the same route as the above-mentioned Iceland bottles. The bottles of the two groups must then by different routes have drifted back to the North-East Atlantic current system and been carried north of the Faroes or through the Faroe-Shetland Channel to Norway by that system. In the more detailed discussion of the currents in the Irminger Sea we shall revert to the drift of these bottles.

The Ireland and Scotland Bottles.

The bottles being divided according to places of stranding, there is, besides the Norway and Iceland bottles, still a rather considerable group from the area under review, namely that of bottles stranding on the coast of Ireland and the west coast of Scotland, including the Hebrides. The launching positions of these bottles lie in a belt along the west coast of Iceland across the Denmark Strait and down along the east coast of Greenland. These bottles, which evidently enter into one of the southerly branches of the North-East Atlantic current, must have passed into that stream rather far to the west, at a point before the North-East Atlantic current commences to branch out, it being highly improbable that these bottles have crossed the entire northeastward branch of the North-East Atlantic current. We will now consider the periods of drift of these bottles.

The bottles stranding on Ireland were recovered after the lapse of the following periods (in days): 488, 594, 618, 754, 865, 913, 935, 943, 1081, 1084 and 1262, whereas the bottles drifting to Scotland have had the following periods of drift: 555, 562, 670, 714, 794, 832, 833 and 942 days. In both cases the minimum period of drift is thus about 500 days, and thereupon the periods are evenly distributed up to upwards of 1000 days. The periods of drift of the bottles will thus be somewhat less on an average that those of the Norway bottles forming Group 3 in Figs. 12 and 13. The long periods of drift confirm the assumption that the Ireland and Scotland bottles and probably also Group 3 of the Norway bottles have drifted along rather a long route before, far to the Southwest, they entered the Gulf Stream. The further elucidation of the tracks will be left to the discussion of the bottles with long periods of drift from the Irminger Sea. In the following we presuppose that all the Ireland and Scotland bottles have commenced with a westerly drift into the Irminger Sea.

Bottles stranding in the Faroes, Shetlands and Orkneys.

Having thus in broad outline explained the routes followed by the Norway bottles, we shall now pass to a consideration of the bottles stranding in the Shetlands, Orkneys and Faroes. From the whole area between 10° and 40° W. and north of 60° N. 14 bottles have stranded on the Orkneys and the Shetlands and 14 on the Faroes. The distribution of the periods of drift of these bottles will appear from the below table:

Shetlands and Orkney Bottles.

Period of drift, days	0—250	251—600	601—650	651—800	>800
Number of bottles	9	0	1	0	4

Faroe Bottles.

Period of drift, days..	0—150	151—300	301—450	451—500	501—650	651—750	>750
Number of bottles....	4	0	3	0	3	0	4

From the former table it will be seen that there is a large interval between the short-term and the long-term bottles. As the 9 fastest bottles are distributed rather evenly through the interval 0—250 days, it must be presumed that these bottles have drifted approximately direct to the place of stranding, whereas the remainder have followed the same route as groups 2 and 3 of the Norway bottles. All the bottles with periods greater than 250 days have, however, so long periods of drift that only the fastest can have taken the same route as Group 2, while the remainder must have followed the track of the Ireland and Scotland bottles.

In the same manner, as far as the Faroe bottles are concerned, the 4 bottles having periods of drift of less than 150 days must have drifted direct to the islands, whereas the others must have commenced with a westward drift. If we compare the bottles having periods of drift of more than 250 days in the two tables, it will appear that far more Faroe bottles than Shetland and Orkney bottles are stranding after relatively short periods of drift. The long-term Faroe bottles most quickly recovered were found after periods of between 300 and 450 days, in other words, after a period slightly greater than the difference in time between groups 1 and 2 of the Norway bottles. These bottles have therefore probably moved along the same track as the bottles of Group 2. The fact that no bottles with the same period of drift are found in the Shetlands indicates that the water masses carrying the bottles of Group 2 to Norway chiefly stream north of the Faroes and not through the Faroe-Shetland Channel.

After this analysis of the periods of drift of bottles with different places of stranding, we should now have a basis for an investigation as to the parts of the area from which the water streams direct to the East and the parts from which it streams northwestwards up along the west coast of Iceland. As far as the Norway bottles are concerned, it will appear from Figs. 12 and 13 that groups 1 and 2 overlap to a certain extent, but that, nevertheless, the limit may with some degree of certainty be fixed at 450 days. In the following it is therefore taken for granted that bottles having a period of drift of less than 450 days have drifted directly eastwards, whereas bottles with longer periods of drift have drifted westwards. In the same manner with regard to the Faroe bottles, the limit between eastward and westward bottles is fixed at 200 days, and for the Shetland and Orkney bottles at 300 days.

It is further taken for granted that all Scotland and Ireland bottles launched north of 60° N. and bottles stranding in Western Greenland and America have entered the westward branch of the North-East Atlantic current. Out of the bottles stranding on the coast of Iceland, only those stranding in Western Iceland, north of the hatched part of the coast in Fig. 15, are included among the bottles drifting westwards into the Irminger Sea, whereas the bottles stranding in Southern Iceland, i. e. south of the line shown in the chart, are not included in the statistics. As far as part of these bottles is concerned, the place of stranding may lie west of the point of launching, but as in all probability the bottles have drifted the last part of their route in the westward coastal current around Iceland, this need not mean that the water masses in which the bottles were launched stream westwards into the Irminger Sea. These Iceland bottles will be studied in more detail later on.

For each field of 1° we will now calculate how many of the bottles launched in the field (bottles drifting to Southern Iceland not included) have drifted eastwards. The result is

shown in Fig. 15, in which in addition the number of bottles launched in the field (South Iceland bottles excluded) is given as a subscript to the percentage figure. In the chart the boundary line between the area from which more than 50 % of the bottles drift eastwards and the area from which more than 50 % drift westwards into the Irminger Sea is plotted. Unfortunately, the data for the western part of the area south of 62° N. are rather sparse, so there the course of the boundary will be uncertain.

As will appear from the chart, the boundary line runs almost from Ingolfshøfde towards the Southwest approximately parallel to the Reykjanes Ridge. The chart shows, however, that even from far inside the area in which the current is preponderantly due east, bottles have been launched which, judging from their periods of drift, have drifted westwards. These bottles are in the main Norway bottles having a period of drift of more than 450 days, but as bottles strand in Norway after long periods of drift both from the Faroe-Shetland Channel and from the waters north of the Faroes, the possibility remains that despite their long periods of drift, some of these bottles have been drifting eastwards.

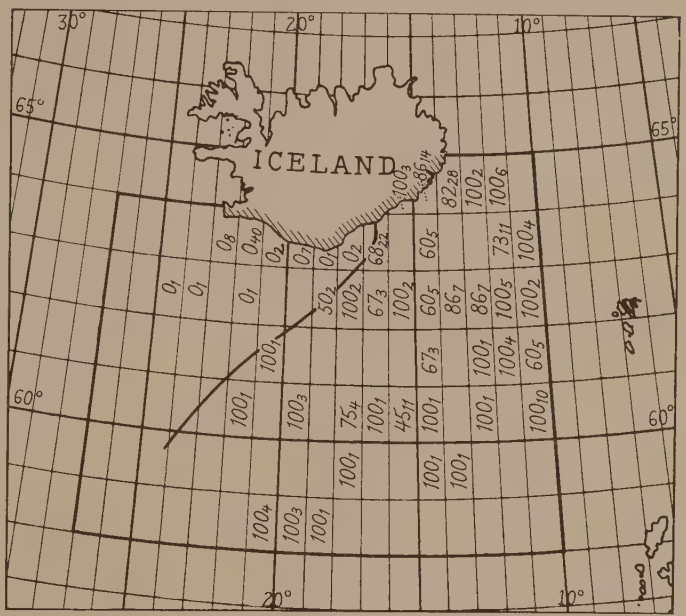


Fig. 15. Percentage of bottles having drifted directly towards the east. Total No. of bottles marked as index.

The picture obtained through these statistics of the current conditions in the waters south of Iceland is definitely in conflict with Ryder's current chart, according to which the water masses of the whole area should stream into the Irminger Sea. Already Dr. J. N. Nielsen has, however, on the basis of drift-bottle experiments in 1905 in the waters south of Iceland called attention to the fact that Ryder's current chart over this area could not be correct.

Bottles stranding in Southern Iceland.

The bottles stranding in Southern Iceland were not included in the above statistics. Most of these bottles were launched in rather close proximity of the south coast of Iceland and have been discussed in the Chapter 3 on the coastal current around Iceland. According to these statistics there should be an eastward current south of the coastal area, and as there must be some mingling of water between this current system and the coastal current, it is only natural that some bottles launched south of the coastal area enter the coastal current and are carried by that current to places of stranding situated west of the places of launching. It is a more curious fact that also from the south-easterly part of the area under review bottles are

drifting to Southern Iceland. If these bottles have drifted direct to the places of stranding, their direction of drift must have been at right angles to the average direction of drift. It would therefore be reasonable to submit these bottles to a closer investigation.

In Fig. 16 the launching and stranding positions have been given for the Iceland bottles launched south of the limit plotted in the chart. The period of drift is given as a subscript to the station number. Of the 9 bottles, 8 were launched in 1900 and one in 1906. This may indicate that in the year 1900 current conditions have deviated from the normal. As Ryder's current chart is mainly based on the bottles from 1900, we find here an explanation of the discrepancy between Ryder's current chart and the picture of the current conditions obtained by the present investigation.

Fig. 16. Bottles launched south-east of Iceland in the year 1900. ○: Launching positions and ×: stranding positions for Iceland recoveries. The numbering of the bottles is marked at launching and stranding positions. The period of drift is marked at launching places. ●: Launching positions for Norway bottles with drift-period less than 400 days. +: Launching positions for Norway bottles with drift-period more than 400 days.

There are, however, various points that indicate that Ryder's current chart does not represent the current conditions of the year 1900 either. As will appear from Fig. 16, there are among the bottles launched in 1900 several Norway bottles with rather short periods of drift. Ryder supposes that the northernmost and westernmost of these bottles drift west and north of Iceland, and thereby makes their tracks conformable to the tracks of the Iceland bottles. As shown in the Chapter 3 on the coastal current around Iceland, this track is an extremely improbable one. The small periods of drift of the bottles indicate that the bottles have drifted approximately direct eastwards.

If we consider the periods of drift of the Iceland bottles, we will find that only 4 of them have had periods of drift of less than 100 days. Among these bottles are the two northernmost ones having station numbers 8 and 9. The drift of these bottles is rather peculiar, as close to the launching place of bottle 8 and almost at the same time 3 bottles were launched which drifted to Norway. As the Iceland bottle stranded after the lapse of only 16 days, ist must be presumed that it has drifted direct north-westwards and entered the coastal current, by which it has then been carried to the place of stranding. As the 3 Norway bottles were launched simultaneously with this bottle, their initial drift must have had the same direction as that bottle until presumably close to the coastal current they have deviated to the South and then eastwards and thus described a circuit before drifting eastwards to Norway. It thus looks as if, at any rate at times, there must be an eddy over the northernmost part of the ridge between the Faroes and Iceland. Bottle 9 has no doubt drifted to the place of stranding by a route similar to that of bottle 8.

The third of the fast Iceland bottles is the one launched in the most westerly position stranding almost due north of the position of launching after 31 days. The direct distance is about 160 miles, so the average rate will be at least 5 miles per day. This rather considerable rate indicates that the bottle has drifted almost directly to the place of stranding, so in the western part of the area we must have a northward stream. South of the coastal area the Norway bottles show that there must have been an eastward current, so in order that the tracks of the

Iceland bottles shall not intersect the other tracks at too large angles, it must be presumed that they commence a westward drift until they enter the area of northward drift, whereupon they drift to the stranding places in Southern Iceland.

Drift-bottle data for the year 1900 thus indicate that at times there is a circuit south of Iceland. The relatively small number of bottles drifting back to Iceland from the southern part of the circuit seem, however, not to indicate that on an average large masses of water participate in this circuit. It is possible that the special drift conditions prevailing in 1900 were due solely to the abnormal wind conditions prevailing in that year. Wind observations from the Westmanna Islands seem to indicate that easterly winds have been predominating during the time after the launching of the bottles.

In other words, we obtain the following picture of the current conditions in the waters between the south coast of Iceland and 60° N.: The north-eastward Irminger current, which is a branch of the North-East Atlantic Current system, divides south of Iceland in a westerly branch streaming northwards along the west coast of Iceland, and an easterly branch streaming eastwards along the shelf at the south coast of Iceland until over the ridge between Iceland and the Faroes it meets the East-Icelandic Current and turns south-eastwards. Some of the water masses stream across the ridge and north of the Faroes into the Norwegian Sea, whereas the remainder stays south of the ridge and drifts west of the Faroes. Part of this branch will no doubt stream through the Faroe-Shetland Channel into the Norwegian Sea, while another part—as will appear from the bottles from 1900—will curve around the banks south-west of the Faroes and to the westward so that a circuit will be created. As mentioned above, this westerly current is presumably not very constant, and the masses of water carried around the circuit are probably rather inconsiderable. The proportion between the water masses streaming north of the Faroes and those streaming through the Faroe-Shetland Channel it is difficult to estimate. The investigation in Chapter 1, page 10, seemed, however, to indicate that by far the greater part of the Norway bottles launched north of 60° N. drifted into the Norwegian Sea north of the Faroes. The current conditions in the waters south of Iceland are shown in the current chart, Fig. 26.

Current Conditions in the Denmark Strait and the Irminger Sea.

Following the investigation of the waters south of Iceland, we shall now endeavour to make a detailed analysis of the current conditions in the Irminger Sea and the Denmark Strait.

Bottles recovered in Iceland.

In Fig. 14, which was drawn on the basis of the Iceland bottles launched between 62° and 67° N. and 22° and 29° W., a very sharp maximum appeared—as mentioned—at about 225 days. From this area 17 bottles were recovered after a period of drift of less than 250 days, whereas 16 have had periods of drift of more than 250 days.

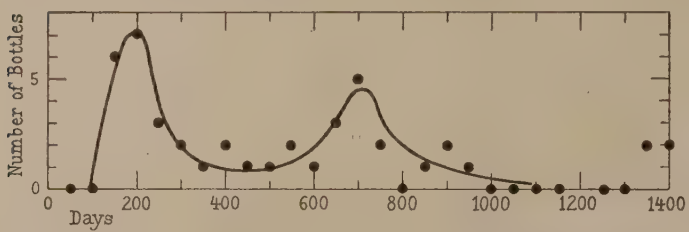


Fig. 17. Frequency distribution of drift time of Iceland bottles launched between 60° N.—67° N. and west of long. 30° W.

From the Irminger Sea west of 30° W. and north of 60° N. 22 bottles have been recovered on the south and west coasts of Iceland. The distribution of the periods of drift of these bottles is shown in Fig. 17, in which the usual grouping of overlapping intervals of 100 days has used. Also here we find a pronounced maximum at about 200 days, and besides a broader maximum at a period of drift of about 700 days. From this area only 7 bottles have been recovered after less than 250 days of drift, whereas 15 have had longer periods of drift. Thus, from the western area relatively far fewer bottles strand after short periods of drift than from the eastern area. Consequently, the circuit in the Irminger Sea, which is represented by bottles having a period of drift of less than 250 days, cannot fill up the entire Irminger Sea. In order to find the limits of the circuit, Fig. 18 shows for each field of 1° the number of bottles from the field stranding in Iceland after periods of drift of less than 250 days, and the number stranding after longer periods of drift. It appears from the chart that of the 7 bottles with short periods of drift launched west of 30° W. 5 were launched east of 33° W. These 5 bottles have had periods of drift of between 187 and 201 days, in other words, on an average slightly less than the period of the circuit. The bottles with the longer periods of drift were, as far as the majority is concerned, launched north and west of these bottles, so on the whole we have reason to think that the 5 fast bottles were launched in the northern and western part of the eddy. Unfortunately, the data from the southern part of the Irminger Sea are so sparse that no southern limit of the circuit may be fixed.

The bottles launched in the western part of the Irminger Sea must on an average have passed through considerably longer distances before they strand than the bottles drifting around the circuit. As will appear from Fig. 18, there are, however, 2 bottles launched west of 40° W. which have been recovered in Iceland after a period of less than 250 days, so at times bottles from the western part of the Irminger Sea may drift to Iceland in relatively short periods. The Iceland bottles with long periods of drift will be discussed together with other bottles with long periods of drift from the Irminger Sea.

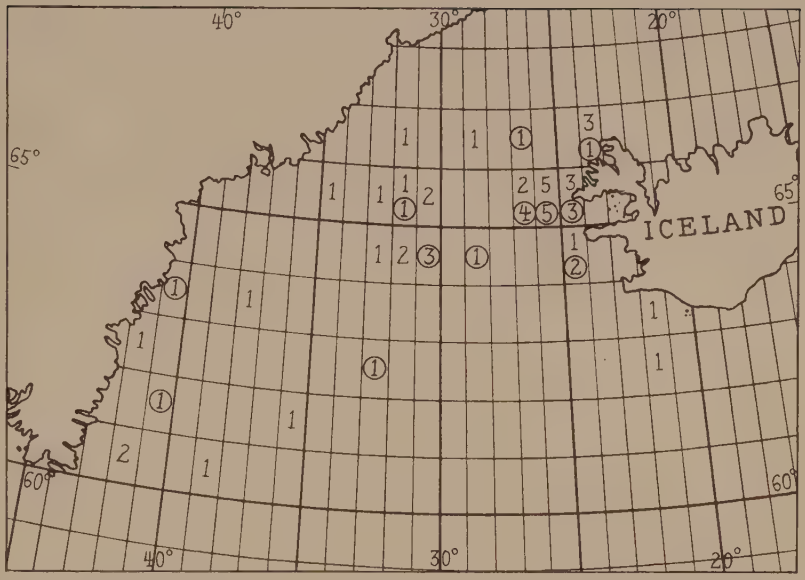


Fig. 18. Bottles recovered on the west and the south coast of Iceland. Figures in circles: Number of bottles with drift-period less than 250 days. Plain figures: Number of bottles with drift-period more than 250 days.

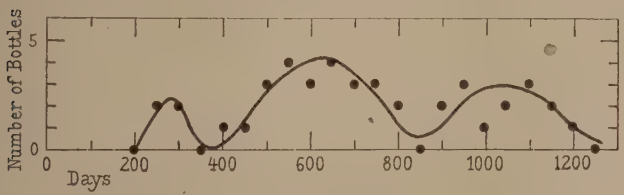


Fig. 19. Frequency distribution of drift time of Norway bottles launched between 60° N.—67° N. and 20° W.—30° W.

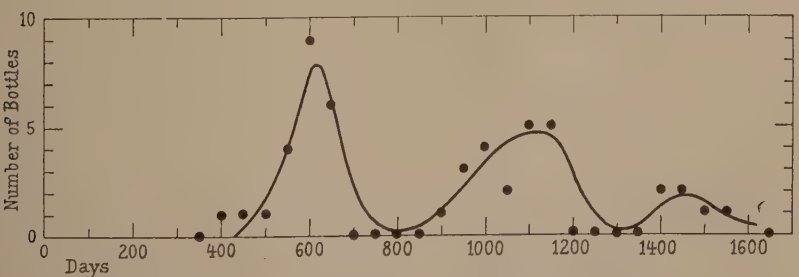


Fig. 20. Frequency distribution of drift time of Norway bottles launched between 60° N.—67° N. and 30° W.—42° W.

Bottles recovered in Norway.

The frequency distribution of the periods of drift of the Norway bottles has been examined in analogy with that of the Iceland bottles and the result appears from Figs. 19 and 20 for the area east of 30°W. and the area west of 30° W. respectively. The two long-term groups seen in Fig. 13 appear plainly in both groups, and on the

whole the difference between the two curves for periods of drift of more than 200 days is not greater than may be explained by statistical error.

In Fig. 21 each field of 1° shows the number of Norway bottles launched in the field and having periods of drift between 200 and 400 days, between 400 and 850 days and upwards of 850 days. The chart shows that the places of launching of the two long-term groups are distributed at random over practically the whole area; only at about 30° W., i. e. in the western part of the circuit, only the group having a period of drift of about 600 days is to be found.

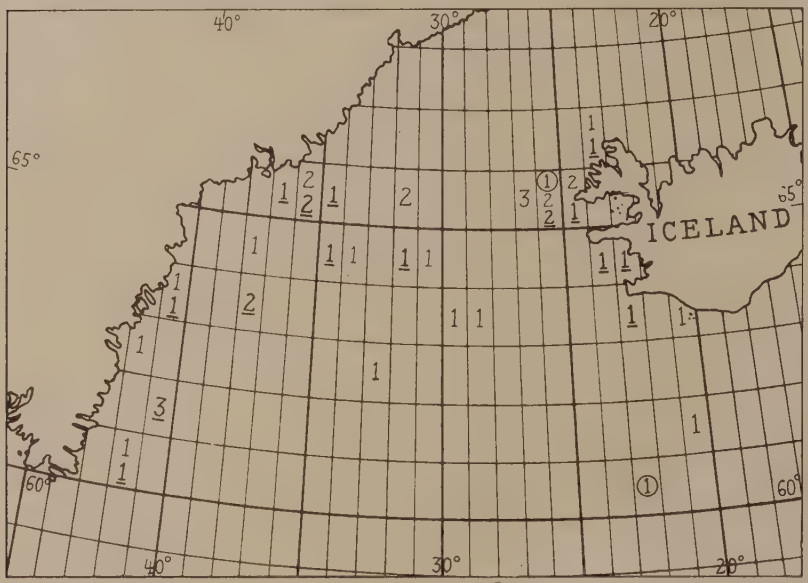


Fig. 21. Bottles recovered on the west coast of Norway. Figures in circles: No. of bottles with drift-period less than 400 days. Plain figures: No. of bottles with drift-period between 400 days and 850 days. Underlined figures: No. of bottles with drift-period more than 850 days.

This distribution of the bottles seems to indicate that there are two different tracks for the Norway bottles with periods of drift of about 600 days. In the first place a number are drifting southward with the western part of the Irminger Sea circuit and then at the southern part of this circuit pass into that branch of the North-East Atlantic current system which later on streams along Southern Iceland and north of the Faroes into the Norwegian Sea. These bottles should thus have passed through the launching area of the Norway bottles on which Fig. 11 was based. The difference between the most frequent periods of drift of these Norway bottles and those under review will be about 300 days, or somewhat longer than the period of the circuit in the Irminger Sea, so the difference between the routes of the two groups will probably be somewhat longer than the circumference of the circuit.

The westernmost Norway bottles having a period of drift of about 600 days were launched off the east coast of Greenland. These bottles have no doubt drifted southward to the level of Cape Farewell when they have presumably entered the eastward water masses and drifted south of the Irminger Sea circuit, and then have followed the route outlined for the bottles commencing with a southward drift in the western part of the Irminger Sea circuit.

As mentioned in page 53, the two bottles launched off the southern part of the east coast of Greenland stranded in Iceland after periods of drift of less than 250 days. From the investigation of the Norway bottles it would be natural to presume that these two bottles have followed the track last outlined until close to the south-west coast of Iceland.

The Norway bottles having periods of drift of upwards of 900 days must have drifted

through considerably longer distances than the bottles having periods of drift of about 600 days. In all probability, they have commenced with a southward drift along the east coast of Greenland until the level of Cape Farewell. Thence they have presumably drifted north-westwards with the West-Greenland Current. These bottles will be discussed in detail in the next Part on bottles with long periods of drift from the Irminger Sea.

We still have to mention the two bottles which stranded on the coast of Norway after periods of drift of less than 300 days. Both bottles were launched between 20° and 30° W. and their launching positions are shown in Fig. 21. One of these bottles was launched so far to the South-East that it must be presumed to have drifted direct eastwards. The other one was launched in 65°42′ N.—25°32′ W. and was recovered after the lapse of 277 days. The only route compatible with the northerly position of launching and the short period of drift is that along the north coast of Iceland and north of the Faroes to Norway. This bottle is probably the only one that has drifted from the Denmark Strait north of Iceland to Norway.

Bottles with long Periods of Drift.

We will now endeavour to elucidate the routes followed by the bottles with long periods of drift, i. e. Iceland bottles with periods of drift of about 700 days, Norway bottles with periods of drift in excess of 900 days, Ireland and Scotland bottles and bottles which after long periods of drift strand on the Orkneys, Shetlands and Faroe Islands. All these bottles that have stranded on the east coasts of the Atlantic must have drifted clear across the Atlantic, and the first parts of their tracks must have had their course in the waters around the coasts of Greenland and North America. It is therefore of great importance for the determination of the tracks of the bottles that a few bottles from the Irminger Sea have stranded on the western coasts of the Atlantic, namely 2, which drifted to the coast of West Greenland and 2 which stranded on Labrador and Newfoundland respectively. Besides, in the waters off Labrador and Newfoundland a number of bottles have been launched which drifted across the Atlantic to the coasts of Europe. We shall now show, how it is possible by comparing the periods of drift of these bottles with the periods of drift of the bottles launched in the Irminger Sea to form a reasonably accurate picture of the tracks of the bottles.

Bottles stranding in West Greenland.

Of the two bottles which from the Irminger Sea have drifted to West Greenland (Fig. 22), one was launched off south-west Iceland and stranded in the southern part of West Greenland after 133 days of drift. This bottle must have drifted northwards along the west coast of Greenland and then across the Denmark Strait and southwards along the east coast of Greenland. The other bottle was launched off the southern part of the east coast of Greenland and was found drifting off Holsteinsborg on the west coast after the lapse of 1094 days. This period of drift is so long that it must be presumed that in some way the bottle has been detained on the route. It may for instance have stranded once and then after staying on the beach for a long time have been refloated.

If we compare these two bottles with the two bottles from the Norwegian Sea area which drifted to West Greenland, we get a confirmation of the well-known fact that part of the East-Greenland Polar Current, probably mingled with Atlantic water from the Irminger Current south of Cape Farewell, curves to the west and then continues as the northward West-Greenland Current.

In order to obtain detailed information as to this current we will now examine the

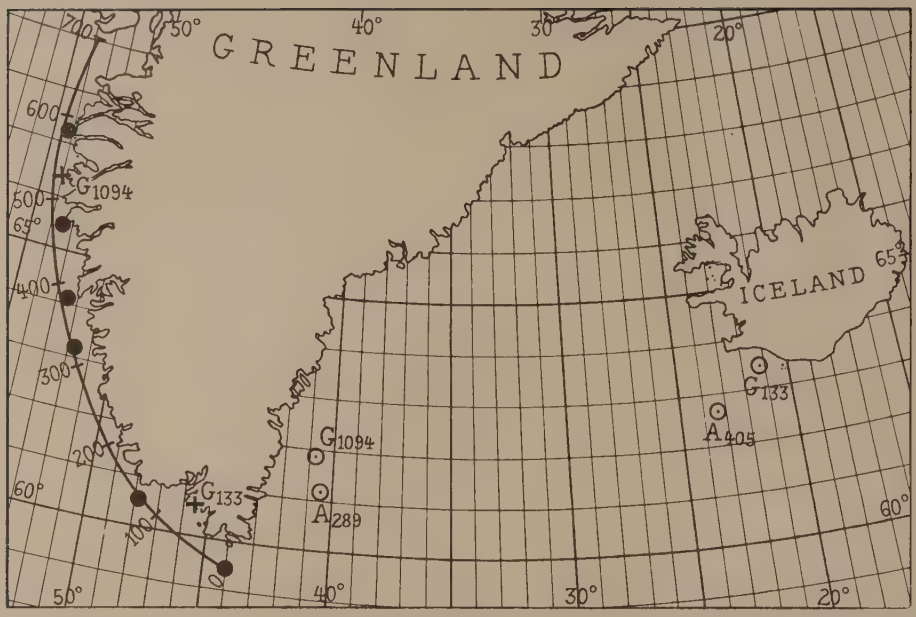


Fig. 22. Scale in naut. miles for measuring distances of drift along the west coast of Greenland. ●: Launching position along the west coast of Greenland. ○: Launching position in the Irminger Sea for bottles having drifted to the west coast of Greenland or to the east coast of North America. Drift time marked as index at the launching positions.

bottles launched along the west coast of Greenland. These bottles were launched from 6 stations (Fig. 22), but from one of them no bottles have been recovered. From the remaining 5 stations a total of 36 bottles was recovered, and all had drifted ashore on the west coast of Greenland and, except for one bottle which was found drifting near the place of launching, they were all recovered north of the positions of launching. The distances drifted by the bottles are measured on a curve along the coast and their rates of drift calculated. Most of the routes are short, the longest one is 400 miles, and 24 of them are less than 100 miles, and in view of the very sparse population of the coast it must be taken for granted that the waiting period for many of the bottles must be considerable in proportion to the period of drift.

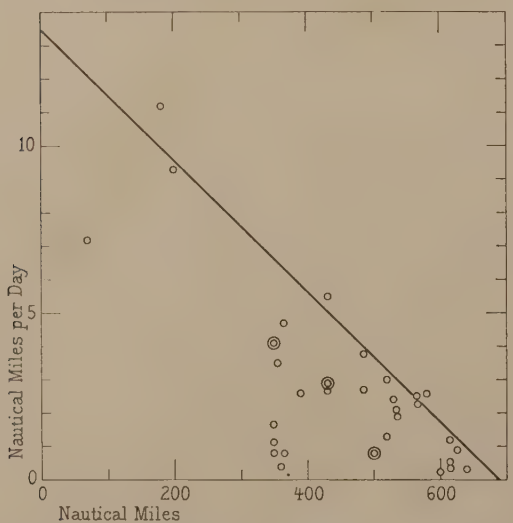


Fig. 23. The rate of the West Greenland Current along the scale in Fig. 22.

In order to ascertain the variation of the current along the coast, the rates of the bottles are plotted in a diagram, Fig. 23, in which the abscissa is the distance along the coast measured from the southernmost position of launching to the centre of the track of the bottle and

the ordinate the rates of drift of the bottles. As might be expected, the points are not lying in a smooth curve, but they plainly show that the rate is declining considerably to the northward. If we consider only the fastest of the bottles, the rate will drop almost straight with the distance from about 11 miles per day at the southernmost part of Greenland to less than 1 mile per day at about 68° N. If we take the rate as a measure of the masses of water streaming along the coast, these masses will thus be decreasing which must mean that great parts of the water masses gradually deviates to the westward and only a slight part continues farther north than to the level of Cumberland. This result is also confirmed (see "Ice conditions in the Arctic Seas", Nautical-Meteorological Annual, 1916, page XXXV) by observations of the icebergs which from the East-Greenland Polar Current drift northwards along the west coast of Greenland. For these observations prove that only very few icebergs drift as far north as Godthaab, whereas by far the greater part drifts to the West before they get so far north.

The water masses must therefore drift westwards until they mingle with the water masses of the Labrador Current.

Bottles stranded in North America.

Besides the Greenland bottles there are 2 bottles of great importance to the research of the current conditions in these waters, namely 2 bottles that have stranded respectively on the coasts of Labrador and Newfoundland. One of these bottles was launched south-west of Reykjanes and the other one east of the southern part of Greenland. These bottles must undoubtedly during the first part of their drift have entered the East-Greenland Polar Current which they must have followed to some place south of Cape Farewell. In the latter part of their drift they must have followed the Labrador Current. In view of the picture we obtained of the current conditions by the analysis of the Greenland bottles, the most reasonable presumption as regards the central part of their route must be that south of Cape Farewell they have drifted westwards and then like the Greenland bottles have followed the northward current along Western Greenland. These bottles do not, however, pass as close to the coast as the Greenland bottles, but have at some place entered the westward water masses which have carried them to the Labrador Current.

As will be seen from the above, the northward West-Greenland Current had decreased to less than 1 mile per day at the narrowest part of the Davis Strait between Cumberland and Egedesminde; consequently, this should constitute the approximate northern boundary of the area from which large masses of water stream to the West to mingle with the Labrador Current.

The two America bottles have had periods of drift of 289 and 405 days respectively, and they are situated one at each end of the zone in which the launching positions of the Ireland and Scotland bottles lie. The difference between their periods of drift is 116 days and fits well with the period of drift of 133 days of the Greenland bottle stranded in the southernmost position, which was launched rather close to one of the America bottles and the place of recovery of which is only about 230 miles from the place of launching of the other America bottle. The time spent by the bottles in the Davis Strait, i. e. the period from their rounding of Cape Farewell until they strand in Labrador or Newfoundland, will be about 270 days, and the distance along the northernmost route up to the proximity of Cumberland will be about 1500 miles, corresponding to an average rate of about 5.5 miles per day.

Bottles launched at Newfoundland and Labrador.

In the waters of Newfoundland and Labrador the "Newfoundland Fishery Research Laboratory" in the years 1932, 33 and 34 launched a number of drift-bottles[1]) of which 21 drifted across the Atlantic. The places of launching and stranding, periods of drift and approximate distance and mean rate will appear from the below table. Unfortunately, the places of stranding are given very roughly, which fact increases the uncertainty in measuring the distances. The launching positions given are taken from the charts in the quoted publications.

It will appear from the table that the rates are far more homogenous than is usually the case in drift-bottle experiments. Most of the bottles were launched in the Labrador Current and must have followed it to the polar front south-east of Newfoundland where they enter the Gulf Stream.

Year	Launched at	Recovered	Period o. drift (days)	Distance (miles)	Rate (miles/day)
1932	54°17′ N.—55°05′ W.	Faroes	436	2240	5.1
	—	Norway	470	2800	6.0
	51°48′ N.—55°40′ W.	Ireland	429	2150	5.0
	49°43′ N.—53°45′ W.	—	343	2000	5.9
	48°50′ N.—53°20′ W.	Azores	431		
	48°20′ N.—51°20′ W.	Shetlands	456	2200	4.8
	43°50′ N.—50°50′ W.	Ireland	434	2000	4.6
	51°48′ N.—55°40′ W.	Faxe Bay, Iceland	610		
1933	54°10′ N.—55°30′ W.	Scotland	339	2150	6.4
	53°40′ N.—56°10′ W.	Skye	456	2100	4.6
	52°20′ N.—55°30′ W.	Shetlands	524	2400	4.6
	50°20′ N.—54°20′ W.	Norway	511	2800	5.5
	45°50′ N.—51°20′ W.	Ireland	371	2000	5.4
1934	50°50′ N.—58°00′ W.	Orkneys	470	2340	5.0
	50°20′ N.—57°50′ W.	Ireland	421	2160	5.1
	50°15′ N.—54°20′ W.	Scotland	422	2000	4.7
	49°20′ N.—52°50′ W.	Scilly Island	432	2100	4.9
	49°00′ N.—52°50′ W.	Ireland	430	2000	4.6
	—	Denmark	505		
	47°20′ N.—49°20′ W.	France	502	2160	4.3
	44°40′ N.—53°10′ W.	—	501	2160	4.3

The 6 bottles that have drifted to Ireland have had periods of drift of 343, 371, 421, 429, 430 and 434 days respectively, and the 2 Scotland bottles have been 339 and 422 days under way. If we assume that the Ireland and Scotland bottles from the Denmark Strait area at first follow the same route as the 2 America bottles and then the same route as the bottles here described, their periods of drift should range between about 630 and 840 days, the maximum and minimum respectively of the sums of the periods of drift of the America bottles and the Newfoundland-Ireland bottles.

[1]) Reports of the Newfoundland Fishery Research Commission, 1933, Vol. II, No. 1, 1934, Vol. II, No. 2, 1935, Vol. II, No. 3.

It is just in this interval that most of the bottles from the Denmark Strait lie. Part of them have, however, longer periods of drift and have possibly gone once round of the Irminger Sea circuit before entering the water masses deviating westward south of Cape Farewell, and part of them may have stayed longer in the Davis Strait than the America bottles.

In a similar manner the two Norway bottles have had periods of drift of 422 and 511 days, corresponding to periods of drift of 800—900 days for the Norway bottles from the Denmark Strait, which is fairly compatible with the period of drift found for Group 3 of the Norway bottles.

To the Faroes, Shetlands and Orkneys the periods of drift are 436, 456, 470 and 524 days, which again corresponds with periods of drift of 800—900 days for bottles from the Denmark Strait to these islands by a route corresponding to that of the Ireland bottles. From the table on page 47 will be seen that most of the periods of drift of the long-term bottles to these islands in conformity are upwards of 750 days.

Finally, one of the Newfoundland bottles was refound in the Faxe Bay in Iceland after the lapse of 610 days. This bottle affords an explanation of the fact that a number of bottles are recovered in Iceland after very long periods of drift (see Fig. 17). In comparison with the bottles which have drifted across the Atlantic, this bottle has had a long period of drift, so possibly it has not drifted direct to the point of stranding; it may, for instance, have drifted once round the Irminger circuit before stranding.

It will be seen that there exists so great a conformity as regards periods of drift and places of stranding between the long-term bottles launched in the Denmark Strait and the bottles launched off Newfoundland that it may be presumed that the latter parts of the routes of the two groups of bottles are identical, however, among the Newfoundland bottles there are some stranding on southerly coasts, where no bottle from the Denmark Strait has been found. These bottles which, judging from the positions of launching, must have been launched either in the Labrador Current or close to the polar front, must evidently have entered the southern branch of the North-East Atlantic current, one of them having been recovered in the Azores, 2 on the coasts of France and one on Scilly Islands off Land's End.

These 4 bottles prove that when only the bottles pass into the Gulf Stream sufficiently far to the West, i. e. at rather a great distance from the areas in which that current branches out, the bottles may subsequently enter any one of the branches. The farther east the bottles enter the North-East Atlantic current, the less the probability of their entering the southern branches of that stream.

The fact that none of the bottles from the Denmark Strait enters the southern branches of the Gulf Stream indicates that only a small part of these bottles passes into the Gulf Stream so far to the West as off Newfoundland; this fact is in conformity with the fact that the two bottles stranding on Labrador and Newfoundland amount to only a small fraction of the bottles which according to the analysis of the periods of drift must have passed this way to the North-East Atlantic current.

Drift-Bottles launched south of 60° N.

From the whole area south of 60° N. and west of 10° W. only 71 bottles have been recovered. Of these 28 were launched around Rockall Bank, whereas the positions of launching of the remaining 43 are scattered over the rest of the vast area.

The bottles from Rockall Bank were launched on the 29th and 30th May, 1908, at 4 stations. The stranding places and periods of drift of the bottles will appear from the following table:

Stranding place	Ireland	Hebrides	Orkneys	Faroes	Norway
Number of bottles	2	6	2	4	13
Periods of drift (days)	58	73, 76, 88	93	141, 150	242, 245, 267,
	123	96, 104, 105	102	173, 851	274, 360, 372,
					422, 443, 465,
					495, 792, 990,
					992

The distribution of the periods of drift of the Norway bottles will appear from Fig. 24. Besides these bottles, one bottles was found adrift off the northern part of East Scotland.

If the bottles were to have drifted direct to the stranding places, their initial tracks would have had widely different directions, which is not probable, as the bottles have been launched almost simultaneously. The bottle with the shortest period of drift was recovered in Ireland after the lapse of 58 days, next come the bottles recovered in the Hebrides and Orkneys, next the bottles recovered in the Faroes, and, finally, the 13 bottles stranding in Norway.

As it must be taken for granted that a great part of the water masses of the North-East Atlantic Current passes northwards between Scotland and Rockall Bank, it would be improbable for the bottles to Ireland to have drifted direct to the places of stranding, i.e. right against the average direction of the current. The most probable explanation of the periods of drift of the bottles is that the bottles commence with a westward drift and then later on turn to the southward, so that off Western Ireland they pass into that branch of the Nort-East Atlantic Current which streams northwards along the west coast of Ireland. Two of the bottles must there have crossed the current on their way to Ireland, while the remainder have followed the current to their respective places of

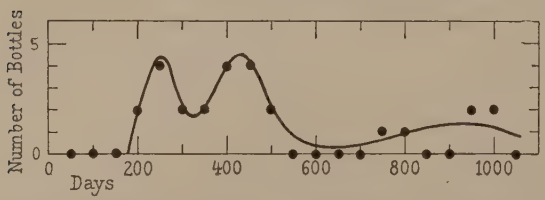


Fig. 24. Frequency distribution of drift time of Norway bottles launched at Rockall Bank.

stranding. However, as regards the Norway bottles, see below. Most of the bottles thus almost follow a circuit. The bottles stranding in the Hebrides show that the period of the circuit will be about 90 days.

All the Norway bottles from these stations stranded in N_4 and N_5 which is a rather curious fact as the bottles have passed through the Faroe-Shetland Channel. The number of bottles is, however, so small that this occurrence may be accidental.

From the curve of distribution of the Norway bottles will be seen that the bottles fall within two groups, namely one with a period of drift of about 250 days and one with a period of drift of about 400 days. This distribution does not seem to be due to differences in positions of stranding. North of Rockall between 59° and 60° N. two bottles have been launched which stranded in Northern Norway after a drift of 220 and 269 days respectively. These bottles were launched so far north that they have probably not entered the circuit around Rockall, but have drifted direct through the Faroe-Shetland Channel. It may therefore be assumed that the 4 Norway bottles from Rockall with periods of drift of about 250 days have entered the water masses streaming direct through the Faroe-Shetland Channel, whereas the group of bottles with longer periods of drift have circled the circuit once.

Next we consider the bottles launched between 15° and 25° W. and between 55° and 60° N. The positions of stranding and the periods of drift appear from the table:

Stranding place	Ireland	Hebrides	Norway	Denmark	Iceland
Number of bottles	1	4	5	1	2
Periods of drift (days)	114	132, 108 105, 106	194, 251 312, 345 426	150	179, 197

The Ireland bottle and one of the bottles drifting to the Hebrides are those launched in the most southerly positions. These bottles have probably passed over into the southward branch of the circuit around Rockall and have then followed the route outlined for the bottles launched at Rockall Bank. Whether the 3 bottles launched in more northerly positions and stranding on the Hebrides have drifted by this route or whether they have drifted to their places of stranding north of Rockall cannot possibly be determined.

The two Iceland bottles are those launched in the westernmost and northernmost positions, respectively, of the bottles under review. These bottles must have passed into the northward branch of the North-East Atlantic Current system. Of the remaining bottles the Norway bottles and that drifting to Denmark have so short periods of drift that they must be assumed to have drifted direct through the Faroe-Shetland Channel.

We then examine the bottles launched between 25° W. and 40° W. Only 3 of these bottles were launched south of 55° N. and only one west of 35° W. The data for these bottles will appear from the table:

Stranding place	Hebrides	Orkneys	Faroes	Norway	Iceland	Sweden
Number of bottles	1	2	2	10	3	1
Periods of Drift (days)	115	173, 210	149, 198	205, 226, 235, 235, 236, 345, 367, 443, 441, 710	125 218 243	534

It will be seen from the table that the Norway bottles still predominate and that their periods of drift on an average are short. The same holds good of the periods of drift of the bottles stranding in the Faroes, the Orkneys and the Hebrides. The 3 Iceland bottles all stranded in the eastern part of the south coast of Iceland.

Probably most of these bottles have drifted north-eastwards and have entered that branch of the North-East Atlantic current system streaming eastward along the south coast of Iceland and continuing north of the Faroes into the Norwegian Sea. The bottle stranding in the Hebrides and probably also the two bottles stranding in the Orkneys have, however, no doubt drifted by a more southerly route.

Finally, we consider the few bottles launched west of 40° W. The data of these bottles will appear from the table:

Stranding places	Ireland	Faroes	Norway	Iceland	Greenland
Number of bottles	1	1	3	1	3
Periods of drift (days)	618	641	580	137	18
			1091		32
			1145		43

The three Greenland bottles have already been included in the analysis of the coastal current along Western Greenland. Of the remaining bottles the Iceland bottle is the only one to strand after a short period of drift. As regards period of drift, this bottle resembles the two previously mentioned Iceland bottles which were launched off Eastern Greenland and recovered in Iceland after a drift of less than 200 days. These three bottles must south of Cape Farewell have drifted eastwards so as to pass south of the Irminger Circuit and then followed the Irminger Current to the place of stranding.

The bottles to Norway, the Faroes and Ireland have according to their long periods of drift passed into the Davis Strait and thence into the Labrador Current, which they have followed until somewhere east of Newfoundland they have passed into the North-East Atlantic Current system.

Hydrographic Conditions in the Irminger Sea.

As it is not possible through the drift-bottle data alone to obtain a sufficiently adequate picture of the intricate current conditions in the Denmark Strait and the Irminger Sea, we shall now make a brief study of the hydrographic conditions in these waters. For this purpose we use the data from the "Meteor" investigations in August 1929 and August 1930[1]). On the basis of these data and other observations G. Böhnecke and A. Defant[2]) calculated the mean temperature, mean salinity and mean specific gravity of the surface water in August and from these data derived the motion of the surface water in the month of August. This current chart shows no circuit in the Irminger Sea. According to Defant's chart there is over the western slope of the Reykjanes ridge an area with greater specific gravity than the surroundings, which according to Defant should be due to ascending bottom water caused by eddies due to a mingling of subarctic and Atlantic water. The ascending bottom water may, however, equally well be due to the effects of the cyclonic circuit which, as we found by the analysis of the drift-bottles, must exist in this area.

It is to be expected that the location of the circuit may be traced through the extension of the Atlantic water masses, as the southward part of the circuit will presumably consist of Atlantic water from the Irminger Current. It would probably be misleading to use the surface salinity as a measure of the extension of the Atlantic water, this water being in many cases - due probably to special wind conditions -covered with a thin layer of water of less salinity. Instead of the surface salinity we therefore use the thickness of the layer of water having a salinity of more than 35 $^{0}/_{00}$ as a measure of the quantity of Atlantic water at a station. In Fig. 25 the thickness of this layer is plotted for each of the "Meteor"'s stations from August 1929 and 1930. In the chart curves have been plotted through areas with the same thickness of layer of Atlantic water. If we consider conditions along sections II and III, it will be seen that over the Reykjanes ridge and east of the ridge Atlantic water extends all the way to the bottom or to depths in excess of 1000 metres. Along the western slope of the ridge there is a minimum of Atlantic water, and when that has been passed, greater thicknesses of Atlantic water are again encountered. Proceeding towards the North-west, we again encounter a tongue

[1]) A. Defant, G. Böhnecke und H. Wattenberg: Die ozeanographischen Arbeiten des Vermessungschiffes "Meteor" in der Dänemarkstrasse und Irmingersee. Veröffentlichungen des Institut für Meereskunde. Reihe A, Heft 32. Berlin 1936.

[2]) G. Böhnecke, E. Hentschel und H. Wattenberg: Über die hydrographischen, chemischen und biologischen Verhältnisse an der Meeresoberfläche zwischen Island und Grönland. Ann. d. Hydr. 1930, H. VII.

G. Böhnecke: Beiträge zur Ozeanographie des Oberflächenwassers in der Dänemarkstrasse und Irminger See. Ann. d. Hydr. Sept. 1931.

A. Defant: Bericht über die ozeanographischen Untersuchungen des Vermessungschiffes "Meteor" in die Dänemarkstrasse und in der Irmingersee. Sitz. Ber. d. Preuss. Akad. d. Wiss., Phys.-Mat. Klasse. 1930 XVI, 1931 XIX, 1936 XIX.

with less quantities of Atlantic water in section III, whereas in an area off the shelf along the east coast of Greenland greater thicknesses of Atlantic water are found. On the shelf proper there is, however, no Atlantic water. This distribution of the Atlantic water is in full conformity with the theory of the circuit and with the extension which according to the drift-bottle ex-

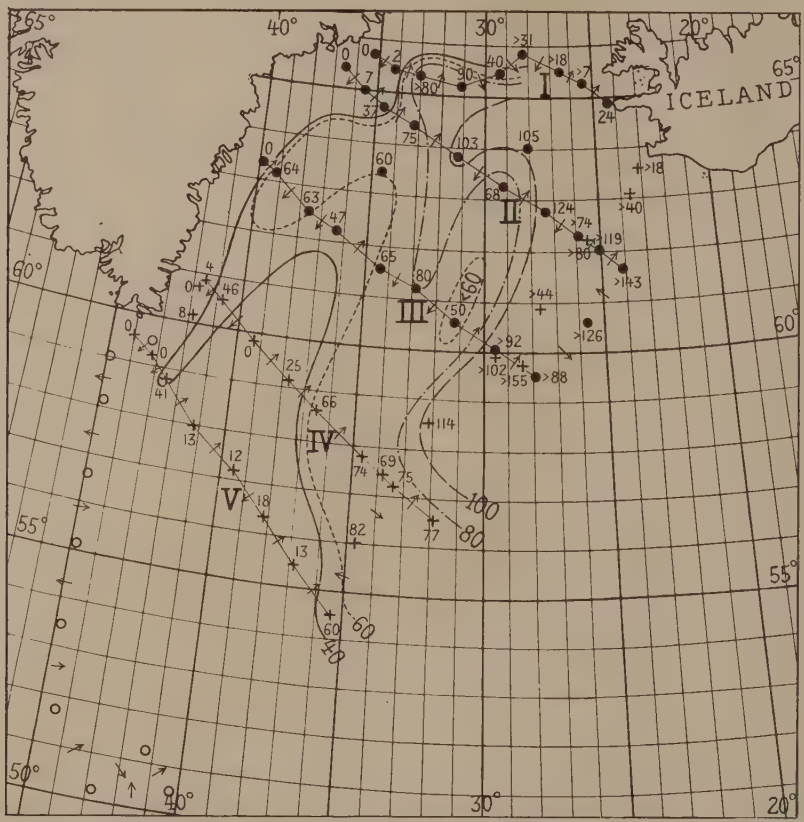


Fig. 25. Distribution of Atlantic water (S ‰ > 35 ‰) in the Irminger Sea. Figures at the stations: Thickness of Atlantic water in decameter. ●: Stations from the "Meteor" expedition August 1929. +: Stations from the "Meteor" expedition August 1930. ○: Stations from the "Meteor" expedition Mars 1935. The arrows between the stations indicate the direction of the surface current computed by dynamical calculations.

periments it must be presumed to have to the West. The minimum of Atlantic water west of the Reykjanes ridge should thus be due to ascending bottom water at the middle of the Irminger circuit. This minimum is situated a little farther to the West than the specific gravity maximum of the surface water in Defant's chart. The tongue of Atlantic water to be found west of the minimum must be situated in the southward part of the circuit. It will be seen how the tongue grows narrower towards the South gradually as the Atlantic water is being mingled with the subarctic water to the westward. This tongue of subarctic water separates the water masses of the circuit from the Atlantic water which extends in a tongue southwards along the shelf

off the east coast of Greenland. The chart shows that this tongue may be traced all the way to the area south of Cape Farewell, but both the horizontal and vertical extensions of the Atlantic water decrease towards the South, gradually as the water is being intermingled partly with the East-Greenland Polar Current to the West, partly with the subarctic water to the East. It is probably the water thus mingled which curves to the West and later on to the North as the West-Greenland Current.

In order further to elucidate the current conditions, a dynamic calculation of the currents has been made on the basis of the "Meteor" data from the years 1929, 1930 and 1935. In the calculation it has been taken for granted that the current is nil at the maximum depth at which samples have been taken at both stations under comparison. At many places this presupposition is no doubt only roughly approximate. As emphasized by DEFANT, the currents in this typical "mingling area" cannot be taken to be stationary and frictionless, so the calculated values of the currents must no doubt to a considerable extent be taken with all reservation. Besides, the currents in the individual sections afford but a momentary picture of conditions and not of the mean movements of the water masses.

In Fig. 25 the calculated sets of the currents are plotted. It appears that on the whole they conform very well with the picture of the current conditions we have previously obtained through the drift-bottle experiments and the investigation of the extension of the Atlantic water masses. The chart shows the north-eastward current east of and over the Reykjanes ridge and the southward current which is assumed to form the western part of the circuit. West of the circuit we find the northward current with subarctic water from the Davis Strait which further to the West mingles with the southward Atlantic water. All the way up along the coast of Greenland we find the southward East-Greenland Polar Current.

On the basis of both drift-bottle experiments and the hydrographic investigations Fig. 26 has been drawn up. It must be observed that this chart only gives a rough outline of the intricate movements of the waters in this area, whereas details such as for instance the stationary eddies in the mingling areas described by DEFANT and BÖHNECKE are not reproduced. For a more detailed current chart far more data than those at present available would be required. Especially it would be desirable to have greater and more evenly distributed drift-bottle data from the Irminger Sea proper. The current chart shows only the direction of the surface current, but neither the rate nor the transport of water masses.

In the chart the different water types are designated by different colours. This does not mean that everywhere there is a constant and definite boundary between the different types of water. As will appear from Fig. 25, there is thus Atlantic water, i. e. water with a salinity of more than 35 $^0/_{00}$, in the greater part of the Irminger Sea, also in the area which according to the current chart is filled up by a tongue of subarctic water. The Atlantic water in this area only appears in smaller thickness and according to Böhnecke's chart[1]) of the mean values of the surface salinity it is covered by a layer of subarctic water. The most definite boundaries between the different types of water will no doubt be found between the Atlantic water and the Labrador Current off Newfoundland.

In order to obtain a more perfect picture of the current conditions, the current chart has been extended to comprise the waters to about 50° N., even if the drift-bottle data alone

[1]) G. BÖHNECKE: Beiträge zur Ozeanographie des Oberflächenwassers in der Dänemarkstrasse und Irminger See. Teil I. Ann. d. Hydr. usw. 1931.

are insufficient to give a picture of the current conditions. The boundary between the subarctic water and the waters of the Gulf Stream in the southwestern part of the chart is taken from Böhnecke's chart of the surface current. In the south-eastern part of the area covered by the chart a special signature is used for the arrows indicating that the course of the current at such places is hypothetical. The current chart of this area must be taken with all reservation.

On the whole it will no doubt appear when in future sufficient data have been compiled for a thorough analysis that many details of this current chart are not correct. On the other hand, there is reason to presume that many of its essential features will on subsequent investigations be found to be approximately in conformity with actual facts.

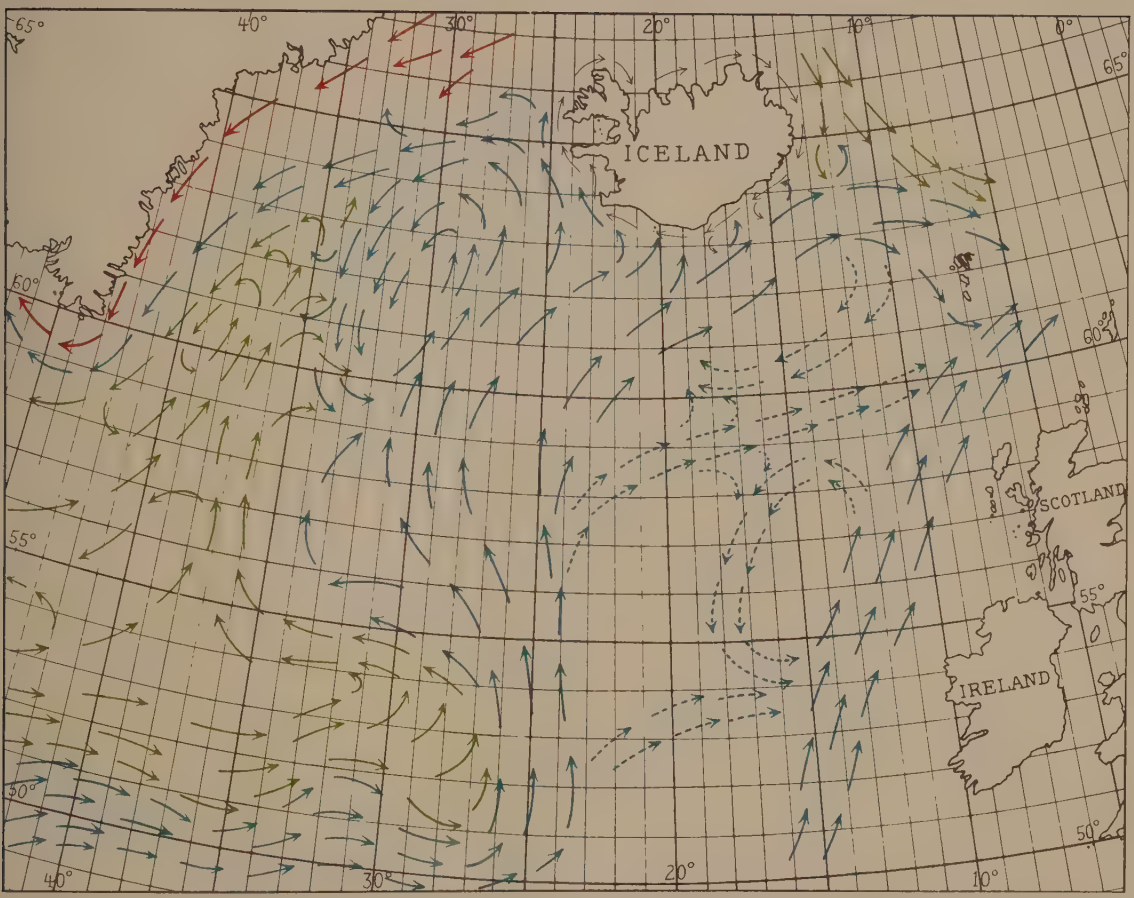


Fig. 26. Surface currents in the northern North Atlantic. Red arrows indicate: Polar water. Green arrows indicate: Subarctic mixed water. Blue arrows indicate: Atlantic water. Black arrows indicate: Coastal water. Dotted arrows indicate hypothetic course of the current.

Dansk Resumé.

I dette Arbejde er der foretaget en Bearbejdelse af alt tilgængeligt Materiale af Strømflasker udsat i den nordlige Del af det nordlige Atlanterhav, i Nordhavet og i Grønlandshavet. I disse Farvande er der ialt udsat 5610 Strømflasker, hvoraf 1224 eller 22 % er genfundet.

I det første Afsnit er Materialet behandlet oversigtsmæssigt, idet der kun er taget Hensyn til Udsætningssteder og Strandingssteder. Kortet (Plate I) viser for hvert Etgradsfelt Antallet af genfundne Flasker udsat i dette Felt, og Tabellerne 1 og 2 giver for hvert af Arealerne A, B, C, D, E, F, G, H, I og K paa Plate I en Oversigt over Antallet af Flåsker genfundet paa forskellige Kyster. Det ses af Tabellen, at Norgesflaskerne er dominerende i næsten alle Omraaderne. Kortet (Plate II) giver en Oversigt over Norgesflaskernes Fordeling angivet i % af samtlige genfundne Flasker. Af Tabellen og Kortet kan man slutte, at kun en ringe Del af Vandmasserne fra Færø-Shetlandkanalen kan passere gennem Areal B, d. v. s. ned gennem den nordlige Del af Nordsøen paa Vej mod Norges Kyst, idet man ikke kan vente, at Norgesflasker fra et Omraade med stor Procentdel af Norgesflasker vil passere gennem Omraader med mindre Procentdel af Norgesflasker.

Det samme Resultat kommer man til ved Betragtning af den Brøkdel af Norgesflaskerne, der strander paa Nordnorge d. v. s. Nord for Lofoten. For de forskellige Arealer faas følgende Procenttal af nordnorske Strandinger, som det ses af Tabel 2: B: 17 %, A: 34 %, C: 61 %, D: 63 %, E: 73 %. Forskellene i Procenttalene for Arealerne A, B og C er saa store, at man kan slutte, at kun en ringe Del af Vandmasserne fra Areal A driver gennem Areal B, og kun en ringe Del af Vandmasserne fra Areal C driver gennem Areal A d. v. s. gennem Færø-Shetlandkanalen. Hovedparten af Flaskerne fra Areal C maa derfor drive Nord om Færøerne til Norge.

Udsætningspositionerne for Flasker strandet paa Irland, Vestskotland, Shetlands- og Orkneyøerne og paa Færøerne fremgaar af Kortet (Plate III). Irlands- og Skotlandsflaskernes Udsætningssteder er fordelt paa to Omraader, nemlig Omraadet omkring og Vest for Rockall Banke og Omraadet langs Vestisland, Danmarkstrædet og langs Østgrønland. Fra første Omraade er Flaskerne antagelig drevet nogenlunde direkte til Strandingsstederne, medens de fra det andet først maa være gaaet over i den østgrønlandske Strøm og af denne ad en eller anden Rute ført til det nordøstatlantiske Strømsystem.

Den største Del af Flaskerne til Færøerne og Shetlands- og Orkneyøerne er foruden i Farvandet rundt om disse Øer dels udsat i en Stribe Nord for Færøerne, langs Østisland og op til Jan Mayen og dels i samme Farvande som Flaskerne, der strandede paa Irland og Vestskotland. Fra det første af disse Omraader er Flaskerne drevet mod Syd med den østislandske Strøm. Flaskerne til Shetlandsøerne maa saaledes have krydset de Vandmasser, der Nord om Færøerne og gennem Færø-Shetlandkanalen driver ind i Nordhavet. De andre Færø- og

Shetlandsflasker maa have fulgt Ruter svarende til de for Irlands- og Skotlandsflaskerne skitserede.

Udsætningsstederne for Islandsflaskerne fremgaar af Kortet (Plate IV).

I Afsnit 2 behandles Færø-Shetlandkanalen mere indgaaende. Diagrammet Fig. 2 giver en Oversigt over Norgesflaskernes Drifttider, idet Flaskernes Rute udmaalt langs Maalestokken Fig. 1 er afsat som Funktion af Drifttiden. Den indtegnede Kurve repræsenterer Forløbet af de hurtigste Flaskers Drift. Kurverne Fig. 3 og 4 viser Fordelingen af Drifttiderne for Flasker strandet paa forskellige Dele af Norges Kyst og for Flasker udsat til forskellige Aarstider. Undersøgelse af Diagrammet og disse Kurver synes ikke at tyde paa, at en væsentlig Del af Flaskerne fra Færø-Shetlandkanalen driver ned gennem den nordlige Del af Nordsøen paa Vej til Norge.

I Nordhavet betragtes Arealerne a, b, c, d og e (Fig. 1) hver for sig, og Fordelingskurverne for Norgesflaskernes Drifttider (Fig. 5) tegnes analogt med Kurverne fra Færø-Shetlandkanalen. Det er dog kun Flaskerne til Nordnorge, der er saa talrige, at man kan tegne Fordelingskurverne for deres Drifttider. For Felterne a og b faas praktisk talt samme Drifttid som for Flasker fra Færø-Shetlandkanalen til Nordnorge nemlig ca. 300 Dage, men Fordelingskurven for Felt b er dog temmelig uregelmæssig. For Felt c den hyppigste Drifttid kun ca. 225 Dage, men det maa bemærkes, at alle Flaskerne her er udsat i samme Aar nemlig 1919. Man maa gaa ud fra, at den lave Drifttid skyldes ekstraordinære høje Hastigheder i dette Aar. Fra Felterne d og e er Materialet saa daarligt, at Fordelingskurverne bliver meget usikre; de hyppigste Drifttider synes dog at ligge omkring 300 til 350 Dage.

Foruden Norgesflaskerne er der fra Nordhavet strandet en Del Flasker paa Island, Færoerne og Shetlandsøerne. Hovedparten af disse Flasker maa have fulgt den østislandske Strøm mod Syd. Fordelingen af Flaskernes Hastigheder fremgaar af Tabellerne pag. 27 og 28. Man ser, at de fleste af Flaskerne har haft Hastigheder mellem 4 og 6 Sømil pr. Dag, saa den østislandske Strøm maa bevæge sig med ret betydelig Hastighed.

De faa Flasker, der er udsat i den vestlige Del af Nordhavet, strander alle efter meget lange Drifttider. Alle Flaskerne er sikkert drevet mod Syd med den østgrønlandske Polarstrøm og nogle af dem er af denne ført til det nordøstatlantiske Strømsystem.

I Afsnit 3 er Kystfarvandet omkring Island behandlet. Som Grænse for Kystomraadet benyttes den punkterede Kurve Fig. 6, der nogenlunde følger 200 m Dybdekurven. Flaskernes Driftlængder er udmaalt langs Kurven Fig. 6, der nogenlunde følger Kysten af Island. Fordelingen af Flaskernes Driftlængder fremgaar af Tabel 3, hvor den anticykloniske Omløbsretning omkring Island er regnet positiv. Det fremgaar af Tabellen, at langt de fleste af Flaskerne er drevet i anticyklonisk Retning. Det maa antages, at Flasker med Drifttid større end 190 Dage er drevet uden for Kyststrømmen. I Tabellen er Flaskerne med Drifttid mindre end 190 Dage inddelt efter Driftlængden i Grupper paa 50 Sømil. Forholdet mellem Flaskeantallet i to paa hinanden følgende Grupper bliver meget nær 2:1. Paa Grundlag heraf beregnes Sandsynligheden for at en Flaske driver en hel Gang rundt om Island eller mere til ca. $^1/_{44000}$, saa man kan se bort fra den Mulighed, at nogle af Flaskerne er drevet mere end en Gang rundt om Island.

Ved Beregning af Kyststrømmens Hastighed betragtes i første Omgang kun Flasker med Driftlængde større end 50 Sømil, idet man herved formindsker Betydningen af Flaskernes Liggetid. Fordelingen af disse Flaskers Hastighed fremgaar af Tabel 4. Den store Spredning i Hastighedsfordelingen tyder paa store Variationer i Kyststrømmens Hastighed. Den gennem-

snitlige Hastighed bliver 3,3 Sømil pr. Dag. Tabellerne 5 og 6 giver en Oversigt over de gennemsnitlige Hastigheder i forskellige Zoner af Kysten (se Fig. 6), idet der stadig kun er benyttet Flasker med Drifttid større end 50 Dage.

De her bestemte Hastigheder er noget for lave, idet der ikke er taget Hensyn til Flaskernes Liggetider. Disse Liggetider kan nu bestemmes, dels ved Sammenligning af to Grupper af Flasker med forskellig gennemsnitlig Driftlængde og dermed forskellig Indflydelse af Liggetiden, og dels ved Betragtning af Flasker med Driftlængde mindre end 50 Dage. Ved sidste Metode findes de virkelige Drifttider ved Hjælp af de tilnærmede Hastigheder i Tabel 5 og Driftlængderne, og ved Subtraktion af de virkelige Drifttider fra Tiden mellem Udsætning og Genfinding faas de gennemsnitlige Liggetider. Efter første Metode findes en gennemsnitlig Liggetid paa 30 Dage og en Gennemsnitshastighed paa 5,2 Sømil pr. Dag. Efter den anden Metode findes for Zone E en gennemsnitlig Liggetid paa 8 Dage og for de andre Zoner slaaet sammen, en Liggetid paa 20 Dage. Naar man reducerer for de sidstnævnte Liggetider faas Hastighederne i Tabel 7. Tabel 9 giver de gennemsnitlige Hastigheder for større Omraader af Kyststrømmen.

Nogle Flasker er fundet drivende; Kortet Fig. 8 viser disse Flaskers Driftruter og Hastigheder. Kortet Fig. 9 giver en Oversigt over Flaskernes Tendens til at forlade Kyststrømmen, idet Tallene i Felterne angiver den Brøkdel af de genfundne Flasker, der har forladt Kystomraadet. Man ser, at der er størst Tendens til at forlade Kystomraadet ved det sydøstlige og det nordvestlige Hjørne af Island.

I Afsnit 4 behandles hele Farvandet Syd og Vest for Island. En Del af Vandmasserne Syd for Island maa sikkert drive mod Øst ind i Nordhavet, medens en Del maa drive med Irmingerstrømmen op langs Vestisland. I dette Afsnit forsøges nu ved Hjælp af en statistisk Undersøgelse af Flaskernes Drifttider, at finde Grænsen mellem Omraadet, hvorfra Vandmasserne hovedsagelig flyder mod Vest, og Omraadet, hvorfra de flyder mod Øst.

Fig. 11b viser Fordelingskurven for Norgesflasker udsat i Omraadet 10°—15° V. og 60°—65° N., Fig. 12 Fordelingskurven for Norgesflasker udsat mellem 15°—42° V. og 60°—67° N., medens Fig. 13 viser Fordelingskurven for Norgesflasker udsat mellem18°—42° V. og 60°—67° N. I Fig. 11b faas en jævn Kurve med Maksimum ved ca. 300 Dage; den hyppigste Drifttid bliver kun lidt længere for dette Omraade end for Færø-Shetlandkanalen, saa Flaskerne herfra er sandsynligvis drevet direkte mod Øst og fortrinsvis Nord om Færøerne ind i Nordhavet. I Fig. 12 og 13 faas 3 Maksimer, et ved ca. 300 Dage, et ved ca. 600 Dage og et ved ca. 1050 Dage. Mens Flaskerne, der danner det første Maksimum sikkert er drevet direkte mod Øst ind i Nordhavet, maa de to Grupper af Flasker med lange Drifttider have begyndt med vestgaaende Drift, og først efter en lang Rute er de igen kommet ind i det nordøstatlantiske Strømsystem. Grænsen mellem de øst- og vestgaaende Norgesflasker kan sættes ved en Drifttid paa 450 Dage. Ved lignende Betragtninger over Drifttiderne for Flasker strandet paa Færøerne, Shetlands- og Orkneyøerne og Skotland og Irland afgøres, hvilke Flasker, der med overvejende Sandsynlighed maa antages at begynde med østgaaende Drift, og hvilke, der maa antages at begynde med vestgaaende. Derefter beregnes for hvert Etgradsfelt, hvormange af de der udsatte Flasker, der er begyndt med østgaaende Drift. Resultatet ses i Fig. 15, hvor der er indtegnet en Grænselinie for Omraadet, hvorfra mere end 50 % af Flaskerne er drevet mod Øst.

Efter denne Undersøgelse foretages en grundigere Undersøgelse af Strømforholdene i Irmingerhavet.

Først betragtes Flaskerne genfundet paa Island, Fig. 14 viser Fordelingskurven for

Islandsflasker udsat mellem 22°—29° V. og 62°—67° N. Kurven viser et meget skarpt Maksimum ved 225 Dage. Da de fleste af Flaskerne er strandet Syd for Udsætningsstedet, kan de ikke have fulgt Kyststrømmen til Strandingsstedet, men de maa have fulgt et Kredsløb i Irmingerhavet.

Fig. 17 viser Fordelingskurven for Islandsflaskerne udsat Vest for 30° V. og Nord for 60° N. Her faas to Maksimer, et ved 200 Dage og et ved ca. 700 Dage. Kortet Fig. 18 viser den geografiske Fordeling af Udsætningssteder for Islandsflasker med Drifttid mindre end 250 Dage og med Drifttid større end 250 Dage. Kortet viser, at næsten ingen af Flaskerne udsat Vest for 33° V. strander efter Drifttid mindre end 250 Dage, saa den vestlige Grænse for Irmingerkredsløbet maa ligge ved ca. 33° V.

Kortet Fig. 21 viser Fordelingen af Norgesflasker med Drifttid mindre end 400 Dage, med Drifttid mellem 400 og 850 Dage og med Drifttid større end 850 Dage. Kun to Flasker har Drifttid mindre end 400 Dage. Udsætningsstederne for de to Grupper af Flasker med lange Drifttider er jævnt blandet mellem hinanden. Kun omkring 30° V. d. v. s. i den vestlige Del af Kredsløbet findes kun Gruppen med Drifttid omkring 600 Dage, saa en Del af denne Gruppes Flasker har sikkert fulgt Irmingerkredsløbet til dets sydlige Del, hvorfra de er drevet med det nordøstatlantiske Strømsystem ind i Nordhavet.

Herefter betragtes Flaskerne med lange Drifttider, d. v. s. Irlands- og Skotlandsflaskerne, Norgesflaskerne med Drifttid større end 850 Dage og Islandsflaskerne med Drifttid omkring 700 Dage. Som Sammenligningsgrundlag benyttes dels fire Flasker udsat i Irmingerhavet og genfundet paa Kysterne af Vestgrønland, Labrador og Newfoundland og dels 21 Flasker, der fra Farvandet ved Labrador er drevet til Europas Kyster. Det viser sig, at Drifttiden Irmingerhavet—Newfoundland + Drifttiden Newfoundland—Nordvesteuropa stemmer ret godt overens med Drifttiden Irmingerhavet—Nordvesteuropa.

Det er derfor sandsynligt, at Flaskerne med lange Drifttider fra Irmingerhavet er drevet ind i Davisstrædet med den vestgrønlandske Strøm og derefter mod Syd med Labradorstrømmen, der fører Flaskerne tilbage til det nordøstatlantiske Strømsystem.

Til Støtte for Strømflaskeundersøgelserne foretages herefter en Undersøgelse af de hydrografiske Forhold i Irmingerhavet. Fig. 25 viser Udbredelsen af det atlantiske Vand og desuden Retningen af Overfladestrømmen bestemt ved dynamiske Beregninger.

Paa Grundlag af Strømflaskeundersøgelserne og de hydrografiske Undersøgelser er Strømkortet Fig. 26 tegnet.

Appendix.

Hitherto unpublished Data.

1908.

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
29/5-08	50	57°09′ N.—13°16′ W.	68°10′ N.—13°20′ E.	Norway	16/2-11	993
			c. 69°45′ N.—18°20′ E.	—	27/2-09	274
			58°25′ N.— 2°24′ W.	At sea	21/9-08	115
			69°08′ N.—16°00′ E.	Norway	5/6-09	372
			67°42′ N.—14°45′ E.	—	14/8-09	442
			56°27′ N.— 6°53′ W.	Scotland	2/9-08	96
			57°27′ N.— 7°23′ W.	—	10/8-08	73
			56°18′ N.— 6°26′ W.	—	25/8-08	88
			c. 69°40′ N.—31°10′ E.	Norway	15/8-09	443
			53°57′ N.—10°12′ W.	Ireland	26/7-08	58
			53°24′ N.—10°14′ W.	—	29/9-08	123
			58°16′ N.— 6°20′ W.	Scotland	11/9-08	105
			58°22′ N.— 7°24′ W.	—	13/6-08	76
29/5-08	25	57°11′ N.—14°00′ W.	59°07′ N.— 3°22′ W.	Shetland	8/9-08	102
			68°30′ N.—14°48′ E.	Norway	26/1-09	242
30/5-08	50	57°15′ N.—15°22′ W.	58°15′ N.— 7°40′ W.	Scotland	11/9-08	104
			70°51′ N.—23°20′ E.	Norway	25/5-09	360
			70°08′ N.—19°25′ E.	—	7/9-09	465
			62°00′ N.— 6°42′ W.	Faroes	27/10-08	150
			68°41′ N.—14°22′ E.	Norway	21/2-09	267
			70°42′ N.—22°45′ E.	—	14/2-11	990
			69°29′ N.—17°20′ E.	—	30/1-09	245
			62°21′ N.— 6°23′ W.	Faroes	28/9-10	851
			70°22′ N.—21°25′ E.	Norway	31/7-10	792
30/6-08	20	57°35′ N.—13°40′ W.	62°18′ N.— 7°13′ W.	Faroes	19/11-08	173
			58°32′ N.— 2°51′ W.	Scotland	31/8-08	93
			70°35′ N.—22°07′ E.	Norway	7/10-09	495
			61°49′ N.— 6°51′ W.	Faroes	18/10-08	141
1/6-08	29	60°31′ N.—15°22′ W.	c. 69°00′ N.—15°00′ E.	Norway	12/4-11	1045
			70°42′ N.—24°20′ E.	—	1/5-11	1064
			70°09′ N.—19°27′ E.	—	10/10-09	496
			70°39′ N.—23°40′ E.	—	2/6-09	366
			63°06′ N.— 8°02′ W.	At sea	19/8-08	79
			69°41′ N.—19°00′ E.	Norway	11/2-11	985

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
7/6-08	25	63°33′ N.—21°00′ W.	64°44′ N.—23°38′ W.	Iceland	11/7-08	34
			64°02′ N.—22°15′ W.	—	11/7-08	34
			63°49′ N.—22°35′ W.	—	12/6-08	5
			64°38′ N.—22°22′ W.	—	30/10-08	145
			63°49′ N.—22°35′ W.	—	30/6-08	23
			64°48′ N.—23°02′ W.	—	16/7-08	39
			63°49′ N.—22°35′ W.	—	20/6-08	13
7/6-08	50	63°39′ N.—21°49′ W.	64°04′ N.—22°33′ W.	Iceland	13/6-08	6
			64°02′ N.—22°31′ W.	—	15/6-08	8
			63°59′ N.—22°30′ W.	—	11/6-08	4
			63°59′ N.—22°30′ W.	—	11/6-08	4
			64°04′ N.—22°33′ W.	—	13/6-08	6
			64°04′ N.—22°42′ W.	—	12/6-08	5
			64°21′ N.—21°58′ W.	—	13/6-08	6
			64°05′ N.—23°36′ W.	—	25/8-08	79
			63°59′ N.—22°30′ W.	—	11/6-08	4
			65°02′ N.—22°58′ W.	—	9/7-08	32
			64°03′ N.—22°04′ W.	—	12/6-08	5
			63°59′ N.—22°30′ W.	—	11/6-08	4
			64°03′ N.—22°04′ W.	—	13/6-08	6
			64°04′ N.—22°33′ W.	—	12/6-08	5
			66°04′ N.—21°27′ W.	—	17/9-08	102
			64°04′ N.—22°33′ W.	—	13/6-08	6
			64°05′ N.—22°36′ W.	—	11/6-08	4
			64°04′ N.—22°33′ W.	—	12/6-08	5
			63°59′ N.—22°30′ W.	—	11/6-08	4
			64°04′ N.—22°33′ W.	—	13/6-08	6
			63°59′ N.—22°30′ W.	—	11/6-08	4
			63°51′ N.—22°41′ W.	—	29/8-08	83
			64°21′ N.—21°58′ W.	—	13/6-08	6
			63°59′ N.—22°30′ W.	—	16/7-08	39
			64°52′ N.—24°00′ W.	—	4/7-08	27
			64°04′ N.—22°33′ W.	—	12/6-08	5
			63°59′ N.—22°30′ W.	—	11/6-08	4
28/6-08	28	64°51′ N.—24°00′ W.	64°54′ N.—23°41′ W.	Iceland	1/7-08	3
			65°16′ N.—24°08′ W.	At sea	30/6-08	2
			64°56′ N.—23°46′ W.	Iceland	22/7-08	24
			64°54′ N.—23°56′ W.	—	3/8-08	36
			57°07′ N.— 8°48′ E.	Denmark	3/7-11	1100
			57°32′ N.— 7°21′ W.	Scotland	29/4-10	670
			64°56′ N.—23°14′ W.	Iceland	12/7-08	14
			64°56′ N.—23°40′ W.	—	30/6-08	2
			65°28′ N.—24°02′ W.	—	20/7-08	22
			66°00′ N.—23°47′ W.	—	12/9-08	76
			64°54′ N.—23°41′ W.	—	3/7-08	5
4/7-08	22	63°32′ N.—21°30′ W.	64°04′ N.—22°42′ W.	Iceland	30/7-08	26
			64°48′ N.—22°24′ W.	—	29/8-08	56

continued

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
4/7-08	22	63°32′ N.—21°30′ W.	63°49′ N.—22°35′ W.	Iceland	15/7-08	11
			64°48′ N.—22°24′ W.	–	29/8-08	56
			63°49′ N.—22°22′ W.	–	16/8-08	43
			63°49′ N.—22°35′ W.		15/7-08	11
			64°47′ N.—22°42′ W.	—	5/8-08	32
			64°47′ N.—22°42′ W.	—	15/7-08	11
			63°49′ N.—22°22′ W.		13/8-08	40
			64°31′ N.—22°17′ W.	—	15/8-08	42
			63°49′ N.—22°35′ W.	—	11/8-08	38
			64°48′ N.—22°51′ W.		8/4-11	1008
5/7-08	25	63°21′ N.—19°05′ W.	64°04′ N.—22°33′ W.	Iceland	14/7-08	9
			63°32′ N.—19°58′ W.	—	29/7-08	24
			63°32′ N.—19°58′ W.		17/7-08	12
			63°31′ N.—19°41′ W.	—	19/7-08	14
			63°23′ N.—19°06′ W.		13/7-08	8
			63°38′ N.—20°29′ W.		30/8-08	56
			63°32′ N.—19°58′ W.		17/7-08	12
			63°44′ N.—20°54′ W.		20/7-08	15
			63°29′ N.—18°06′ W.		2/10-08	89
			63°23′ N.—19°03′ W.		14/7-08	9
			63°29′ N.—19°30′ W.		18/7-08	13
			63°32′ N.—19°58′ W.		29/7-08	24
			64°04′ N.—22°33′ W.		14/7-08	9
			63°32′ N.—19°58′ W.		14/7-08	9
			63°28′ N.—19°27′ W.		17/7-08	12
			63°32′ N.—20°03′ W.	– –	14/7-08	9
			63°52′ N.—21°43′ W.		23/7-08	18
			63°29′ N.—19°30′ W.	– –	18/7-08	13
			63°28′ N.—19°27′ W.	– –	17/7-08	12
11/7-08	25	63°46′ N.—16°33′ W.	71°01′ N.—24°10′ E.	Norway	24/6-10	713
			63°08′ N.— 7°41′ E.		6/9-09	421
			68°06′ N.—13°35′ E.		10/8-09	395
			66°30′ N.—12°06′ E.		1/9-09	416
			66°24′ N.—12°30′ E.		29/10-08	110
			63°39′ N.—17°48′ W.	Iceland	?	?
			63°48′ N.—16°54′ W.		7/11-08	119
			65°43′ N.—11°48′ E.	Norway	22/5-11	1043
			66°12′ N.—17°09′ W.	Iceland	25/7-08	379
12/7-08	25	64°11′ N.—14°51′ W.	63°33′ N.—17°52′ W.	Iceland	13/5-09	305
			68°36′ N.—14°30′ E.	Norway	12/2-11	945
			63°48′ N.—17°02′ W.	Iceland	25/7-09	378
14/7-08	15	65°49′ N.—24°49′ W.	63°43′ N.—20°41′ W.	Iceland	23/6-09	346
			58°00′ N.— 0°20′ W.	At sea	13/7-10	729
			55°32′ N.— 8°24′ E.	Denmark	24/2-11	955

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
20/7-08	25	66°36′ N.—22°13′ W.	66°08′ N.—21°40′ W.	Iceland	11/9-08	53
			66°03′ N.—21°30′ W.	—	11/9-08	53
			66°11′ N.—21°47′ W.	—	29/8-08	40
			66°08′ N.—21°40′ W.	—	28/8-08	39
21/7-08	10	66°35′ N.—18°53′ W.	66°13′ N.—17°12′ W.	Iceland	15/8-08	25
			66°00′ N.—17°28′ W.	—	16/8-08	26
			66°04′ N.—17°27′ W.	—	12/8-08	22
			66°27′ N.—16°30′ W.	—	18/8-08	28
			65°36′ N.—13°56′ W.	—	29/8-08	39
			66°10′ N.—16°48′ W.	—	29/8-08	39
21/7-08	10	66°24′ N.—18°42′ W.	66°20′ N.—16°27′ W.	Iceland	11/8-08	21
			65°56′ N.—18°12′ W.	—	6/8-08	16
			66°02′ N.—18°16′ W.	—	4/8-08	14
			66°13′ N.—16°30′ W.	—	28/8-08	38
			65°32′ N.—13°12′ W.	—	29/8-08	39
			66°17′ N.—16°28′ W.	—	11/8-08	21
26/7-08	25	66°38′ N.—16°24′ W.	66°15′ N.—15°14′ W.	Iceland	2/11-08	99
			65°33′ N.—13°41′ W.	—	25/8-08	30
			66°14′ N.—15°30′ W.	—	11/8-08	16
			66°14′ N.—15°30′ W.	—	8/8-08	13
			65°50′ N.—14°20′ W.	—	11/8-08	16
			66°14′ N.—15°30′ W.	—	18/8-08	23
			65°17′ N.—13°40′ W.	—	25/8-08	30
			66°22′ N.—14°29′ W.	—	5/8-08	10
			65°46′ N.—14°32′ W.	—	29/8-08	34
			66°20′ N.—14°29′ W.	—	7/8-08	12
			71°02′ N.—24°35′ E.	Norway	21/9-10	787
26/7-08	10	66°33′ N.—16°22′ W.	65°37′ N.—14°10′ W.	Iceland	10/8-08	15
26/7-08	10	66°23′ N.—14°24′ W.	63°48′ N.—17°04′ W.	Iceland	17/6-09	326
			65°36′ N.—13°56′ W.	—	14/6-10	688
			66°20′ N.—14°29′ W.	At sea	27/7-08	1
			66°20′ N.—14°29′ W.	—	28/7-08	2
			66°20′ N.—14°29′ W.	—	3/8-08	8
			66°21′ N.—14°33′ W.	Iceland	28/7-08	2
			63°29′ N.—18°06′ W.	—	6/5-09	283
27/7-08	5	66°23′ N.—13°55′ W.	63°30′ N.—18°00′ W.	Iceland	26/4-09	272
27/7-08	5	66°22′ N.—13°19′ W.	63°29′ N.—18°06′ W.	Iceland	8/5-09	284
2/8-08	10	64°35′ N.—13°52′ W.	70°36′ N.—22°00′ E.	Norway	4/11-09	459
			68°51′ N.—16°00′ E.	—	28/5-09	299
			70°05′ N.—17°35′ E.	—	5/7-09	337
			66°07′ N.—16°50′ W.	Iceland	4/7-09	336

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
3/8-08	6	64°26′ N.—13°26′ W.	62°13′ N.— 6°28′ W.	Faroes	13/6-09	314
			68°37′ N.—14°32′ E.	Norway	22/9-09	415
			70°32′ N.—30°35′ E.	—	19/2-09	200
			71°03′ N.—23°50′ E.	--	27/5-10	662

1928.

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
14/4-28	25	63°09′ N.—19°00′ W.	58°30′ N.— 4°40′ W.	Scotland	25/7-30	832
			63°57′ N.—22°42′ W.	Iceland	18/5-28	34
			63°57′ N.—22°42′ W.	—	15/5-28	31
			66°00′ N.—12°15′ E.	Norway	5/12-30	962
			53°37′ N.—10°13′ W.	Ireland	14/10-30	913
			64°00′ N.—23°40′ W.	At sea	4/5-28	20
			64°09′ N.—22°03′ W.	Iceland	31/5-28	47
			69°05′ N.—15°30′ E.	Norway	4/6-31	1146
15/4-28	25	63°41′ N.—22°02′ W.	63°33′ N.—22°05′ W.	Iceland	19/4-28	4
			63°33′ N.—22°05′ W.	—	19/4-28	4
			58°13′ N.— 6°23′ W.	Scotland	26/7-30	832
			63°55′ N.—22°39′ W.	Iceland	13/5-28	34
			64°02′ N.—22°06′ W.	—	18/5-28	33
			63°57′ N.—22°42′ W.	—	16/5-28	31
17/4-28	25	64°40′ N.—23°53′ W.	64°55′ N.—23°53′ W.	At sea	21/4-28	4
			64°54′ N.—24°03′ W.	—	19/4-28	2
			64°55′ N.—23°56′ W.	—	20/4-28	3
			69°53′ N.—29°58′ E.	Norway	1/6-31	1140
			64°55′ N.—24°03′ W.	Iceland	19/4-28	2
18/4-28	24	65°31′ N.—24°37′ W.	—			
18/4-28	25	66°31′ N.—22°28′ W.	66°25.5′ N.—22°30′ W.	Iceland	4/5-28	16
19/4-28	23	66°16′ N.—20°01′ W.	66°10′ N.—16°40′ W.	Iceland	25/6-28	67
			66°05′ N.—17°43′ W.	—	25/6-28	67
			65°28′ N.—21°22′ W.	—	15/6-28	57
			65°36′ N.—20°36′ W.	—	10/5-28	21
31/5-28	45	66°15′ N.—19°18′ W.	70°50′ N.—25°15′ E.	Norway	15/4-29	319
			65°57′ N.—18°23′ W.	Iceland	20/6-28	20
			66°09′ N.—18°35′ W.	At sea	1/6-28	1
			65°45′ N.—12°23′ E.	Norway	22/3-29	295
			66°09′ N.—18°35′ W.	At sea	1/6-28	1

continued

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
31/5-28	45	66°15′ N.—19°18′ W.	70°50′ N.—25°15′ E.	Norway	17/6-29	377
			65°58′ N.—18°31′ W.	Iceland	17/6-28	17
			66°09′ N.—18°35′ W.	At sea	1/6-28	1
			66°09′ N.—18°35′ W.	—	1/6-28	1
			65°41′ N.—18°05′ W.	Iceland	8/6-28	8
			65°58′ N.—18°24′ W.	—	5/6-28	5
			65°58′ N.—18°31′ W.	—	6/6-28	6
			66°10′ N.—18°22′ W.	—	4/6-28	4
27/6-28	41	65°11.5′ N.—13°23′ W.	68°32.5′ N.—15°13′ E.	Norway	23/3-29	269
			62°15′ N.— 6°39′ W.	Faroes	15/11-28	141
			70°32′ N.—22°15′ E.	Norway	21/1-29	208
			63°24′ N.—18°48′ W.	Iceland	23/8-28	57
			69°42′ N.—18°25′ E.	Norway	10/1-29	198
			70°15′ N.—19°32′ E.	—	8/11-29	499
			c. 70°05′ N.—18°40′ E.	—	19/4-29	296
			68°35′ N.—15°10′ E.	—	13/8-29	412
			64°36′ N.—14°08′ W.	Iceland	8/7-28	11
			c. 71°00′ N.—27°10′ E.	Norway	19/5-32	1422
30/5-28	47	66°28′ N.—22°23′ W.	66°20.5′ N.—22°15′ W.	Iceland	8/9-28	101
			65 36.5′ N.—21°24′ W.	—	21/6-28	22
			66°01′ N.—21°39′ W.	—	20/6-28	21
			66°01′ N.—21°31′ W.	—	10/6-28	11
			66 03.5′ N.—21°44′ W.	—	17/6-28	18
			65°36′ N.—21°22′ W.	—	15/6-28	16

1929.

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
14/2-29	100	63°34.5′ N.—21°03.5′ W.	60°28′ N.—45°29′ W.	Greenland	27/6-29	133
			55°18′ N.— 7°06′ W.	Ireland	1/10-30	594
22/2-29	100	65°22′ N.—24°25′ W.	66°08.5′ N.—16°45′ W.	Iceland	19/6-29	117
			66°09′ N.—17°52′ W.	—	30/4-29	67
			66°23′ N.—22°19′ W.	—	15/7-29	143
8/3-29	100	65°16′ N.—13°23′ W.	62°15′ N.— 7°42′ W.	At sea	13/6-29	97
			63°45′ N.—17°21′ W.	Iceland	5/2-32	1064
			63°58′ N.—22°45′ W.	—	8/6-29	92
			70°58′ N.—24°00′ E.	Norway	3/3-30	360
			61°57′ N.— 6°52′ W.	Faroes	2/10-29	208
			63°35′ N.—18°00′ W.	Iceland	18/3-32	1106
			62°09′ N.— 7°10′ W.	Faroes	28/11-29	265

continued

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
8/5-29	100	65°16′ N.—13°23′ W.	69°45′ N.—18°12′ E.	Norway	14/2-30	343
			69°16′ N.—15°55′ E.	—	5/3-30	362
			63°49′ N.— 8°37′ E.	—	10/11-29	247
			70°30′ N.—30°38′ E.	—	24/3-30	381
			62°03′ N.— 6°49′ W.	Faroes	26/11-29	263
			70°45′ N.—22°42′ E.	Norway	23/2-30	352
			62°00′ N.— 5°05′ E.	—	12/10-31	948
			61°38′ N.— 6°55′ W.	Faroes	26/10-29	232
			62°06′ N.— 7°28′ W.	—	14/11-29	251
			c. 63°40′ N.—20°25′ W.	Iceland	6/10-31	942
			70°12′ N.—30°30′ E.	Norway	27/3-30	384
			63°45′ N.—17°40′ W.	Iceland	31/12-30	663
			68°00′ N.—13°10′ E.	Norway	11/11-29	248
			64°53′ N.—11°05′ E.	—	19/12-29	286
			71°08′ N.—25°52′ E.	—	4/3-32	1092
			63°39′ N.—17°48′ W.	Iceland	15/6-29	99
			63°20′ N.— 7°58′ E.	Norway	30/9-29	191
			62°18′ N.— 7°08′ W.	Faroes	7/6-31	821
			65°59′ N.—12°25′ E.	Norway	3/1-30	301

1931.

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
30/5-31	10	47°06′ N.—18°29′ W.	—			
2/6-31	10	43°05′ N.—18°05′ W.	—			
4/6-31	10	40°46′ N.—18°35′ W.	—			
6/6-31	15	37°04′ N.—18°48′ W.				
7/6-31	10	34°37′ N.—21°53′ W.	—			
8/6-31	20	32°56′ N.—23°47′ W.	—			
10/6-31	10	34°32′ N.—25°32′ W.	—			
11/6-31	10	37°04′ N.—23°39′ W.	—			
14/6-31	10	37°15′ N.—25°49′ W.				
15/6-31	10	37°58′ N.—27°39′ W.				
19/6-31	10	39°13′ N.—27°24′ W.	—			
20/6-31	10	39°57′ N.—24°59′ W.				
21/6-31	20	41°37′ N.—27°00′ W.	38°38′ N.—27°09′ W.	Azores	30/7-31	39
			38°38′ N.—27°13′ W.	—	20/7-31	29
23/6-31	20	41°55′ N.—32°22′ W.	39°45′ N.—31°07′ W.	Azores	10/7-31	17
			39°23′ N.—31°11′ W.	—	12/7-31	19
25/6-31	20	43°39′ N.—24°04′ W.	—			
26/6-31	10	45°51′ N.—28°51′ W.	—			

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
$^{27}/_{6}$-31	20	47°02′ N.—31°45′ W.	—			
$^{29}/_{6}$-31	10	47°36′ N.—28°39′ W.	—			
$^{30}/_{6}$-31	10	50°22′ N.—31°14′ W.	58°55′ N.—11°00′ E.	Sweden	$^{15}/_{12}$-32	534
$^{1}/_{7}$-31	10	53°38′ N.—29°41′ W.	67°25′ N.—13°55′ E.	Norway	$^{22}/_{2}$-32	236
			67°32′ N.—14°41′ E.	—	$^{16}/_{9}$-32	443
$^{4}/_{7}$-31	10	58°32′ N.—27°14′ W.	67°03′ N.—13°47′ E.	Norway	$^{17}/_{9}$-32	441
			64°00′ N.— 9°12′ E.	—	$^{24}/_{2}$-32	235
			64°07′ N.—10°12′ E.	—	$^{25}/_{2}$-32	236
			65°28′ N.—12°08′ E.	—	$^{24}/_{2}$-32	235
$^{14}/_{7}$-31	25	64°47′ N.—24°31′ W.	57°34′ N.— 7°23′ W.	Scotland	$^{10}/_{3}$-34	942
			66°02′ N.—14°50′ W.	Iceland	$^{5}/_{7}$-32	357
			63°49′ N.—21°38′ W.	—	$^{31}/_{1}$-32	201
			64°45′ N.—22°26′ W.	—	$^{24}/_{2}$-32	225
$^{14}/_{7}$-31	25	65°26′ N.—24°30′ W.	64°45′ N.—23°40′ W.	Iceland	$^{21}/_{2}$-32	222
			66°27′ N.—22°36′ W.	—	$^{20}/_{2}$-32	221
			64°32′ N.—10°46′ E.	Norway	$^{30}/_{9}$-34	1174
$^{14}/_{7}$-31	25	65°35′ N.—25°00′ W.	66°12′ N.—21°42′ W.	Iceland	$^{28}/_{3}$-32	258
			70°50′ N.—28°26′ E.	Norway	$^{1}/_{4}$-33	627
			54°51′ N.— 8°29′ W.	Ireland	$^{11}/_{2}$-34	943
			64°15′ N.—23°24′ W.	Iceland	$^{15}/_{3}$-32	245
$^{15}/_{7}$-31	25	65°42′ N.—25°32′ W.	c. 65°12′ N.—10°36′ E.	Norway	$^{13}/_{7}$-34	1094
			66°05′ N.—21°41′ W.	Iceland	$^{6}/_{11}$-31	114
			64°48′ N.—22°59′ W.	—	$^{26}/_{2}$-32	226
			54°48′ N.— 1°19′ W.	England	$^{10}/_{12}$-33	879
			66°04′ N.—21°36′ W.	Iceland	$^{4}/_{11}$-31	112
			63°51′ N.— 8°25′ E.	Norway	$^{17}/_{4}$-32	277
$^{15}/_{7}$-31	25	65°50′ N.—26°08′ W.	63°54′ N.—22°42′ W.	Iceland	$^{21}/_{2}$-32	221
			65°27′ N.—24°05′ W.	—	$^{18}/_{2}$-32	218
$^{15}/_{7}$-31	25	65°55′ N.—26°35′ W.	63°51′ N.—21°07′ W.	Iceland	$^{14}/_{2}$-32	214
$^{15}/_{7}$-31	25	66°02′ N.—26°55′ W.	64°48′ N.—23°03′ W.	Iceland	$^{23}/_{2}$-32	223
$^{15}/_{7}$-31	10	c. 66°05′ N.—28°25′ W.	—			
$^{16}/_{7}$-31	10	c. 65°59′ N.—30°00′ W.	—			
$^{16}/_{7}$-31	10	c. 65°31′ N.—31°59′ W.	64°03′ N.—22°45′ W.	Iceland	$^{2}/_{2}$-32	201
$^{16}/_{7}$-31	15	c. 65°16′ N.—34°08′ W.	63°39′ N.—17°46′ W.	Iceland	$^{25}/_{6}$-33	710
			65°20′ N.— 6°15′ E.	At sea	$^{6}/_{8}$-34	1117

1932.

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
8/7-32	25	65°26′ N.—24°31′ W.	64°29′ N.—22°15′ W.	Iceland	26/1-33	202
			71°06′ N.—27°39′ E.	Norway	2/8-34	755
			63°32′ N.—20°15′ W.	Iceland	18/6-34	710
			64°45′ N.—23°40′ W.	—	3/6-34	695
8/7-32	25	65°42′ N.—25°32′ W.	64°45′ N.—23°40′ W.	Iceland	22/1-33	198
			c. 63°30′ N.—18°00′ W.	—	1/4-34	632
			c. 63°35′ N.—20°20′ W.	—	17/1-33	193
			66°59′ N.—13°42′ E.	Norway	30/5-34	691
			70°54′ N.—25°32′ E.	—	14/2-35	951
			c. 60°10′ N.— 1°10′ W.	Shetland	18/11-34	863
			62°08′ N.— 7°25′ W.	Faroes	19/4-35	1015
			64°50′ N.—23°58′ W.	Iceland	28/9-34	812
8/7-32	25	65°49′ N.—26°37′ W.	65°28′ N.—24°03′ W.	Iceland	13/7-33	370
			64°29′ N.—22°19′ W.	—	25/1-33	201
			63°25′ N.—20°20′ W.	—	23/9-33	442
			67°40′ N.—12°25′ E.	Norway	14/4-34	645
			65°40′ N.—12°10′ E.	—	31/1-34	572
9/7-32	10	66°10′ N.—28°00′ W.	63°50′ N.—21°20′ W.	Iceland	12/8-33	399
9/7-32	10	66°22′ N.—29°20′ W.	63°40′ N.—17°50′ W.	Iceland	11/7-33	367
9/7-32	10	65°58′ N.—31°50′ W.	65°06′ N.—11°44′ E.	Norway	20/4-34	650
10/7-32	10	65°23′ N.—32°14′ W.	—			
10/7-32	10	65°25′ N.—33°50′ W.	—			
10/7-32	10	65°13′ N.—35°15′ W.	—			
10/7-32	10	64°48′ N.—36°35′ W.	—			
12/7-32	15	62°40′ N.—40°40′ W.	57°07′ N.— 6°13′ W.	Scotland	10/8-34	759
12/7-32	10	62°40′ N.—41°20′ W.	—			
14/7-32	20	64°38′ N.—32°06′ W.	—			
14/7-32	20	64°38′ N.—30°10′ W.	63°32′ N.—19°48′ W.	Iceland	26/1-33	196
			c. 64°47′ N.—23°37′ W.	—	22/1-33	192
			63°49′ N.—22°41′ W.	—	17/1-33	187
			69°36′ N.—18°05′ E.	Norway	28/1-34	563
14/7-32	20	64°52′ N.—28°35′ W.	66°17′ N.—22°10′ W.	Iceland	6/2-33	207
25/7-32	35	66°42′ N.—16°10′ W.	66°58′ N.—15°17′ W.	At sea	8/9-32	45

continued

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
$^{25}/_{7}$-32	35	66°42′ N.—16°10′ W.	66°30′ N.—16°12′ W.	Iceland	$^{31}/_{7}$-32	6
			70°23′ N.—21°29′ E.	Norway	$^{30}/_{5}$-33	309
			64°03′ N.—11°15′ E.	—	$^{7}/_{9}$-33	409
			70°46′ N.—23°00′ E.	—	$^{6}/_{5}$-33	285
			70°22′ N.—22°35′ E.	—	$^{24}/_{8}$-34	760
			70°04′ N.—28°56′ E.	—	Oct. 33	c. 440
			70°58′ N.—28°31′ E.	—	$^{20}/_{2}$-34	575
$^{25}/_{7}$-32	25	66°35′ N.—16°10′ W.	66°30′ N.—16°40′ W.	Iceland	$^{28}/_{7}$-32	3
			66°31′ N.—16°26′ W.	—	$^{16}/_{8}$-32	22
			66°22′ N.—14°55′ W.	—	$^{26}/_{9}$-32	63
			66°31′ N.—16°26′ W.	—	$^{22}/_{8}$-32	28
			66°23′ N.—16°36′ W.	—	$^{4}/_{9}$-32	41
			66°31′ N.—16°26′ W.	—	$^{18}/_{8}$-32	24
			66°31′ N.—16°26′ W.	—	$^{18}/_{8}$-32	24
			66°31′ N.—16°26′ W.	—	$^{20}/_{8}$-32	26
			66°19′ N.—18°05′ W.	At sea	$^{7}/_{8}$-32	13
			66°31′ N.—16°26′ W.	Iceland	$^{20}/_{8}$-32	26

1933.

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
$^{7}/_{8}$-33	25	66°53′ N.—23°18′ W.	64°02′ N.—22°43′ W.	Iceland	$^{14}/_{8}$-36	1103
			66°05′ N.—12°40′ E.	Norway	$^{14}/_{8}$-35	737
			63°35′ N.—21°46′ W.	Iceland	$^{3}/_{4}$-34	239
$^{8}/_{8}$-33	25	65°26′ N.—24°30′ W.	70°31′ N.—22°41′ E.	Norway	$^{4}/_{6}$-35	665
$^{8}/_{8}$-33	25	65°40′ N.—25°33′ W.	57°18′ N.— 7°23′ W.	Scotland	$^{21}/_{2}$-35	562
			61°50′ N.— 6°53′ W.	Faroes	$^{10}/_{9}$-34	398
			63°52′ N.—21°10′ W.	Iceland	$^{29}/_{3}$-34	233
			64°28′ N.—21°59′ W.	—	$^{24}/_{1}$-36	899
			63°50′ N.—21°20′ W.	—	$^{28}/_{9}$-35	781
			60°05′ N.— 1°21′ W.	Shetland	$^{26}/_{10}$-36	1175
			c. 57°20′ N.— 7°25′ W.	Scotland	$^{14}/_{2}$-35	555
$^{9}/_{8}$-33	25	65°37′ N.—30°07′ W.	51°28′ N.— 9°49′ W.	Ireland	$^{23}/_{1}$-37	1262
			63°38′ N.—17°48′ W.	Iceland	$^{21}/_{6}$-35	681
			63°26′ N.—20°16′ W.	—	$^{8}/_{3}$-35	576
$^{10}/_{8}$-33	25	65°58′ N.—31°00′ W.	63°37′ N.—17°51′ W.	Iceland	$^{5}/_{6}$-37	1395
			62°18′ N.— 6°54′ W.	Faroes	$^{5}/_{10}$-35	786
			68°23′ N.—13°42′ E.	Norway	$^{11}/_{3}$-35	578

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
11/8-33	25	63°38′ N.—40°13′ W.	63°40′ N.—20°30′ W.	Iceland	13/2-34	187
			65°09′ N.—11°30′ E.	Norway	8/6-36	1034
			70°09′ N.—28°47′ E.	—	7/4-35	604
			c. 57°15′ N.— 7°25′ W.	Scotland	26/7-35	714
12/8-33	25	63°27′ N.—39°45′ W.	—			
12/8-33	25	62°10′ N.—41°45′ W.	64°48′ N.—23°06′ W.	Iceland	3/6-37	1391
			63°51′ N.— 8°27′ E.	Norway	13/5-35	639
			52°23′ N.— 9°50′ W.	Ireland	31/7-36	1084
13/8-33	25	61°57′ N.—40°41′ W.	64°41′ N.—22°25′ W.	Iceland	20/2-34	191
			55°16′ N.— 8°14′ W.	Ireland	29/7-36	1081
			66°20′ N.—54°15′ W.	At sea	11/8-36	1094
13/8-33	25	60°39′ N.—41°53′ W.	64°41′ N.—22°25′ W.	Iceland	3/5-35	659
			68°18′ N.—13°35′ E.	Norway	29/8-36	1102
15/8-33	20	61°52′ N.—35°30′ W.	63°32′ N.—20°10′ W.	Iceland	12/7-35	696
16/8-33	20	62°36′ N.—32°48′ W.	62°12.7′ N.— 6°41.8′ W.	Faroes	31/5-36	1019
			c. 53°45′ N.— 9°54′ W.	Ireland	8/3-36	935
			64°29′ N.—22°15′ W.	Iceland	28/2-34	196
			70°09′ N.—19°25′ E.	Norway	12/3-35	573
17/8-33	10	63°38′ N.—25°59′ W.	—			

1934.

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
18/5-34	25	64°05′ N.—15°31′ W.	70°11′ N.—19°40′ E.	Norway	15/3-35	301
			69°36′ N.—17°42′ E.	—	2/1-35	229
			68°36′ N.—14°32′ E.	—	22/3-35	308
18/5-34	25	64°12′ N.—14°52′ W.	64°03′ N.—15°11′ W.	Iceland	21/5-34	3
			69°10′ N.—15°50′ E.	Norway	11/5-35	358
			65°07′ N.—11°39′ E.	—	18/7-35	426
			68°12′ N.—13°30′ E.	—	5/6-35	383
			c. 63°30′ N.—18°00′ W.	Iceland	16/5-36	729
18/5-34	25	64°02′ N.—14°41′ W.	65°58′ N.—12°15′ E.	Norway	1/2-35	259
			70°35′ N.—22°06′ E.	—	7/3-35	293
			69°46′ N.—19°03′ E.	—	17/6-35	395
			70°47′ N.—23°17′ E.	—	28/3-35	314
			63°51′ N.—21°21′ W.	Iceland	25/9-34	130

continued

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
18/5-34	25	64°02′ N.—14°41′ W.	c. 63°47′ N.— 8°37′ E.	Norway	17/8-36	822
			69°58′ N.—20°38′ E.	—	4/4-35	321
			69°07′ N.—15°40′ E.	—	19/3-35	305
			69°39′ N.—17°58′ E.	—	23/5-35	370
18/5-34	10	63°52′ N.—14°30′ W.	70°30′ N.—23°54′ E.	Norway	9/9-36	845
18/5-34	10	63°42′ N.—14°19′ W.	71°05′ N.—27°59′ E.	Norway	3/7-35	411
			c. 68°18′ N.—13°49′ E.	—	30/3-35	316
			71°02′ N.—27°25′ E.	—	27/1-35	254
			66°30′ N.—15°58′ W.	Iceland	4/11-36	911
19/5-34	10	64°25′ N.—14°18′ W.	71°00′ N.—23°54′ E.	Norway	14/3-35	299
			71°04′ N.—26°04′ E.	At sea	25/1-35	251
19/5-34	10	64°21′ N.—13°46′ W.	70°53′ N.—23°19′ E.	Norway	15/3-35	300
			70°18′ N.—22°20′ E.	—	8/7-35	415
			71°03′ N.—27°30′ E.	—	12/3-35	297
			70°52′ N.—24°33′ E.	—	21/2-35	278
			70°25′ N.—31°05′ E.	—	8/4-35	324
19/5-34	25	64°17′ N.—13°00′ W.	68°18′ N.—13°40′ E.	Norway	6/12-34	201
			70°03′ N.—20°29′ E.	—	22/3-35	307
			66°03′ N.—12°00′ E.	—	23/1-35	249
			63°39′ N.— 8°12′ E.	—	18/11-34	183
			66°35′ N.—12°15′ E.	—	20/2-35	277
			69°38′ N.—17°58′ E.	—	19/9-36	854
			69°38′ N.—18°01′ E.	—	30/5-35	376
			69°53′ N.—30°11′ E.	—	4/8-35	442
22/5-34	10	66°22′ N.—14°27′ W.	66°18′ N.—14°25′ W.	At sea	23/5-34	1
22/5-34	10	66°22′ N.—14°01′ W.	65°49′ N.—14°48′ W.	Iceland	23/6-34	32
22/5-34	10	66°22′ N.—13°35′ W.	65°37′ N.—14°09′ W.	Iceland	23/6-34	32
			64°58′ N.—13°46′ W.	—	23/6-34	32
			65°12′ N.—13°47′ W.	—	25/6-34	34
			70°31′ N.—30°23′ E.	Norway	29/3-35	311
22/5-34	10	66°22′ N.—13°00′ W.	70°23′ N.—21°26′ E.	Norway	12/5-35	355
			65°49′ N.—14°48′ W.	Iceland	23/6-34	32
			64°56′ N.—13°43′ W.	—	13/8-34	83
			64°42′ N.—13°49′ W.	—	2/7-34	41
			69°30′ N.—17°23′ E.	Norway	6/5-35	349
			64°53′ N.—13°47′ W.	Iceland	15/9-34	116
23/5-34	10	66°22′ N.—12°33′ W.	64°28′ N.—10°13′ E.	Norway	21/2-35	274
23/5-34	10	66°22′ N.—11°53′ W.	65°29′ N.—12°14′ E.	Norway	21/1-35	243

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
23/5-34	10	66°22′ N.—10°17′ W.	67°16′ N.—13°56′ E.	Norway	5/6-35	378
			69°37′ N.—17°34′ E.	—	4/6-35	377
23/5-34	10	66°24′ N.— 8°01′ W.	69°39′ N.—17°57′ E.	Norway	15/6-35	388
			65°01 ′N.—10°53, E.	—	1/6-35	374
24/5-34	10	66°22′ N.— 6°26′ W.	64°31′ N.—10°51′ E.	Norway	2/10-36	862
25/5-34	10	63°33′ N.— 5°30′ W.	69°32′ N.—41°13′ E.	At sea	12/10-35	505
			70°11′ N.—30°23′ E.	Norway	6/4-35	316
			70°16′ N.—19°35′ E.	—	27/10-36	886
25/5-34	10	62°56′ N.— 5°30′ W.	70°35′ N.—22°06′ E.	Norway	23/2-35	274
			71°08′ N.—25°20′ E.	—	2/3-35	281
25/5-34	10	62°40′ N.— 5°30′ W.	70°43′ N.—23°56′ E.	Norway	13/3-35	292
			71°05′ N.—25°40′ E.	—	12/9-35	475
			71°01′ N.—24°07′ E.	—	30/11-34	189
			71°02′ N.—24°58′ E.	—	3/1-35	223
			63°27′ N.— 7°00′ E.	—	25/7-34	61
27/5-34	15	61°30′ N.— 5°40′ W.	70°16′ N.—19°12′ E.	Norway	25/4-35	333
			70°19′ N.—20°12′ E.	—	11/7-35	410
			71°20′ N.—31°10′ E.	—	19/5-35	357
27/5-34	20	61°30′ N.— 6°05′ W.	68°10′ N.—13°20′ E.	Norway	7/12-34	194
			70°35′ N.—22°06′ E.	—	30/11-34	177
			68°45′ N.—39°39′ E.	Russia	16/9-35	477
			c. 68°20′ N.—14°00′ E.	Norway	8/10-38	1594
			70°14′ N.—30°33′ E.	—	5/4-35	313
			67°08′ N.—13°56′ E.	—	30/12-36	948
			71°06′ N.—24°42′ E.	—	3/4-35	311
			60°23′ N.— 1°24′ W.	Shetland	25/8-34	90

1935.

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
28/3-35	25	61°30′ N.— 6°05′ W.	c. 70°25′ N.—21°50′ E.	Norway	29/5-36	428
			63°02′ N.— 7°42′ E.	—	4/8-35	129
			63°40′ N.— 8°17′ E.	—	28/10-35	214
			63°21′ N.— 7°56′ E.	—	23/10-36	575
			60°37′ N.— 1°25′ W.	Shetland	2/8-35	127
			69°41′ N.—18°40′ E.	Norway	23/9-36	545
			63°20′ N.— 8°00′ E.	—	28/10-35	214
			62°04′ N.— 0°45′ E.	At sea	12/7-35	106

continued

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
$^{28}/_{3}$-35	25	61°30′ N.—6°05′ W.	63°05′ N.— 7°36′ E.	Norway	$^{23}/_{10}$-35	209
			c. 60°25′ N.— 1°30′ W.	Shetland	$^{1}/_{6}$-35	65
			64°18′ N.—10°17′ E.	Norway	$^{29}/_{8}$-35	154
			60°08′ N.— 1°04′ W.	Shetland	$^{15}/_{6}$-35	79
			c. 69°20′ N.—17°41′ E.	Norway	$^{25}/_{6}$-36	455
$^{28}/_{3}$-35	25	61°30′ N.— 5°40′ W.	65°36′ N.—11°54′ E.	Norway	$^{26}/_{8}$-35	151
			59°57′ N.— 1°21′ W.	Shetland	$^{27}/_{9}$-35	183
			64°29′ N.—10°30′ E.	Norway	$^{1}/_{7}$-35	95
			62°03′ N.— 0°40′ E.	At sea	$^{21}/_{6}$-35	85
$^{28}/_{3}$-35	25	61°30′ N.— 6°22′ W.	63°30′ N.— 8°26′ E.	Norway	$^{10}/_{5}$-36	409
			59°53′ N.— 1°17′ W.	Shetland	$^{25}/_{6}$-35	89
			65°02′ N.—11°11′ E.	Norway	$^{5}/_{5}$-38	1132
			60°25′ N.— 0°45′ W.	Shetland	$^{21}/_{5}$-35	54
			c. 60°20′ N.— 1°05′ W.	—	$^{21}/_{5}$-35	54
			67°04′ N.—14°03′ E.	Norway	$^{24}/_{9}$-36	546
			c. 61°30′ N.— 5°00′ E.	—	$^{14}/_{10}$-35	200
			64°31′ N.—10°48′ E.	—	$^{13}/_{9}$-35	169
			59°18′ N.— 2°30′ W.	Orkney	$^{29}/_{5}$-35	62
$^{30}/_{3}$-35	25	62°31′ N.— 6°58′ W.	c. 58°40′ N.— 3°00′ W.	Scotland	$^{6}/_{6}$-35	68
			62°14′ N.— 6°35′ W.	Faroes	$^{3}/_{4}$-35	4
			65°48′ N.—11°37′ E.	Norway	$^{11}/_{10}$-36	561
			c. 60°45′ N.— 0°50′ W.	Shetland	$^{12}/_{5}$-35	43
			67°54′ N.—13°05′ E.	Norway	$^{28}/_{9}$-36	548
			c. 60°25′ N.— 1°05′ W.	Shetland	$^{7}/_{8}$-35	130
			60°24′ N.— 1°06′ W.	—	$^{8}/_{6}$-35	70
			60°47′ N.— 2°45′ E.?	At sea	$^{27}/_{5}$-35	58
			62°03′ N.— 7°06′ W.	Faroes	$^{27}/_{5}$-35	58
			62°13′ N.— 6°42′ W.	—	$^{3}/_{4}$-35	4

1938.

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
$^{23}/_{6}$-38	25	53°48′ N.—20°21′ W.	—			
$^{25}/_{6}$-38	25	55°28′ N.—20°21′ W.	56°35′ N.— 6°20′ W.	Scotland	$^{4}/_{11}$-38	132
$^{25}/_{6}$-38	25	56°48′ N.—20°21′ W.	c. 55°06′ N.— 8°22′ W.	Ireland	$^{17}/_{10}$-38	114
$^{26}/_{6}$-38	25	58°08′ N.—20°21′ W.	c. 57°45′ N.— 7°00′ W.	Scotland	$^{12}/_{10}$-38	108
			57°15′ N.— 7°30′ W.	—	$^{9}/_{10}$-38	105
			c. 57°09′ N.— 7°30′ W.	—	$^{10}/_{10}$-38	106

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
27/6-38	25	59°08′ N.—20°21′ W.	—			
28/6-38	25	60°02′ N.—19°43′ W.	c. 63°43′ N.— 8°40′ E.	Norway	6/10-41	1191
			71°00′ N.—23°54′ E.	—	7/6-39	344
			c. 70°42′ N.—30°12′ E.	—	29/4-39	305
			70°40′ N.—22°30′ E.	—	18/2-39	235
28/6-38	25	60°10′ N.—17°44′ W.	70°00′ N.—18°40′ E.	Norway	6/5-39	312
			69°40′ N.—18°00′ E.	—	3/5-39	309
			71°03′ N.—27°15′ E.	—	21/4-39	297
			c. 71°00′ N.—27°30′ E.	—	21/10-39	480
29/6-38	25	60°15′ N.—15°06′ W.	71°06′ N.—25°22′ E.	Norway	22/6-39	358
			63°40′ N.— 8°40′ E.	—	10/2-39	226
			70°40′ N.—21°59′ E.	—	17/6-39	353
			71°04′ N.—24°09′ E.	—	6/3-40	615
30/6-38	20	60°33′ N.—10°41′ W.	67°40′ N.—12°40′ E.	Norway	4/12-38	157
			60°45′ N.— 0°50′ W.	Shetland	21/9-38	83
			58°48′ N.— 3°00′ W.	Orkney	5/12-38	158
			59°08′ N.— 2°35′ W.	—	20/9-38	82
			c. 68°20′ N.—14°00′ E.	Norway	10/11-38	133
2/7-38	20	60°35′ N.—10°21′ W.	70°24′ N.—31°02′ E.	Norway	8/6-39	341
			c. 60°50′ N.— 0°50′ W.	Shetland	18/9-38	78
			c. 70°09′ N.—20°09′ E.	Norway	12/6-39	345
3/7-38	20	61°59′ N.—10°54′ W.	70°49′ N.—26°44′ E.	Norway	8/5-39	309
			71°02′ N.—24°15′ E.	—	28/9-39	452
4/7-38	20	61°58′ N.—14°28′ W.	62°11′ N.— 6°49′ W.	Faroes	29/9-38	87
			69°42′ N.—18°30′ E.	Norway	6/7-39	367
5/7-38	20	61°56′ N.—20°09′ W.	c. 69°48′ N.—19°30′ E.	Norway	22/9-39	444

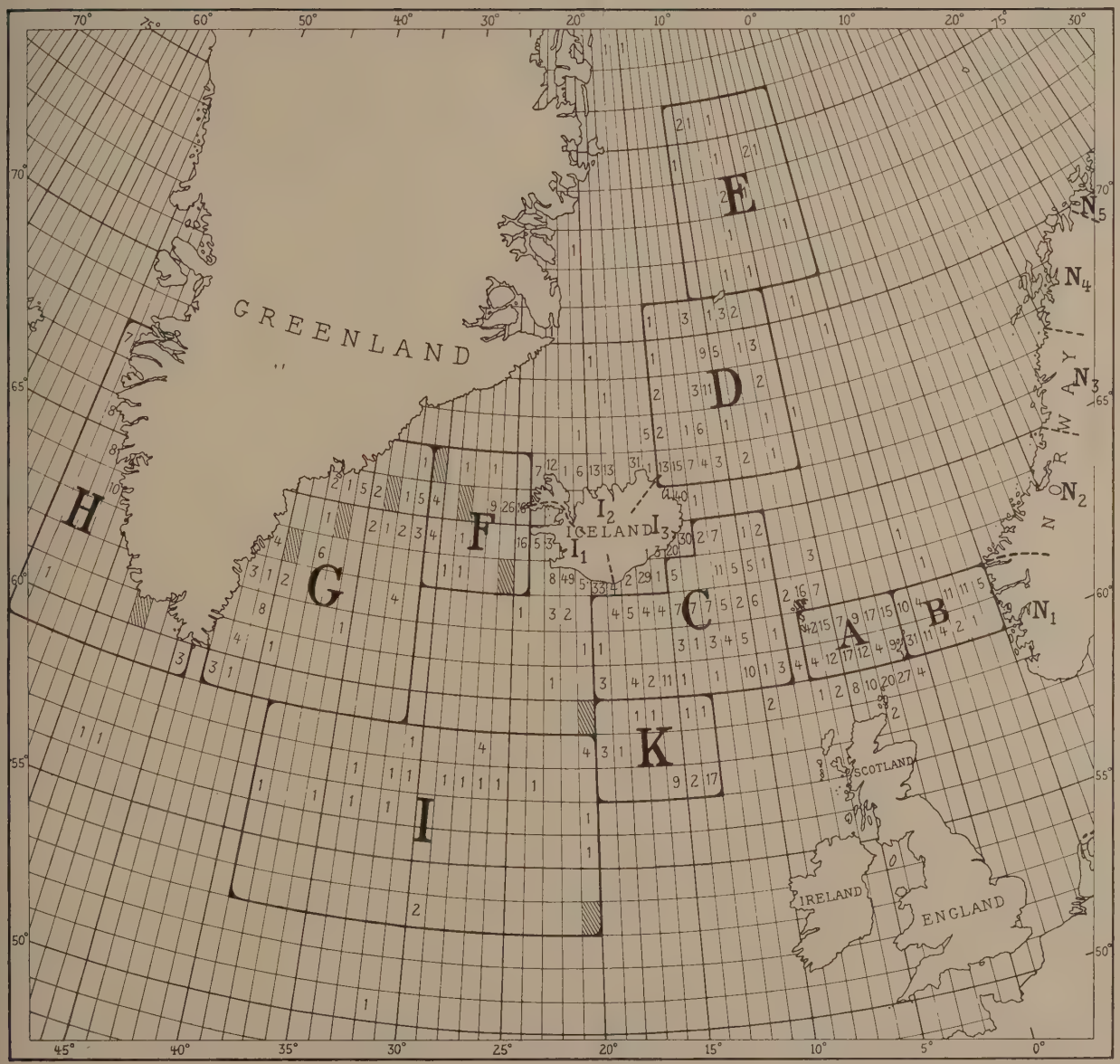
1939.

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
12/6-39	25	64°07′ N.—52°25′ W.	67°58′ N.—53°34′ W.	Greenland	13/12-39	184
			c. 65°02′ N.—52°20′ W.	—	1/7-39	19
			65°03′ N.—52°21′ W.	—	22/6-39	10
			66°51′ N.—53°38′ W.	—	15/8-39	64
			c. 65°02′ N.—52°20′ W.	—	2/7-39	20

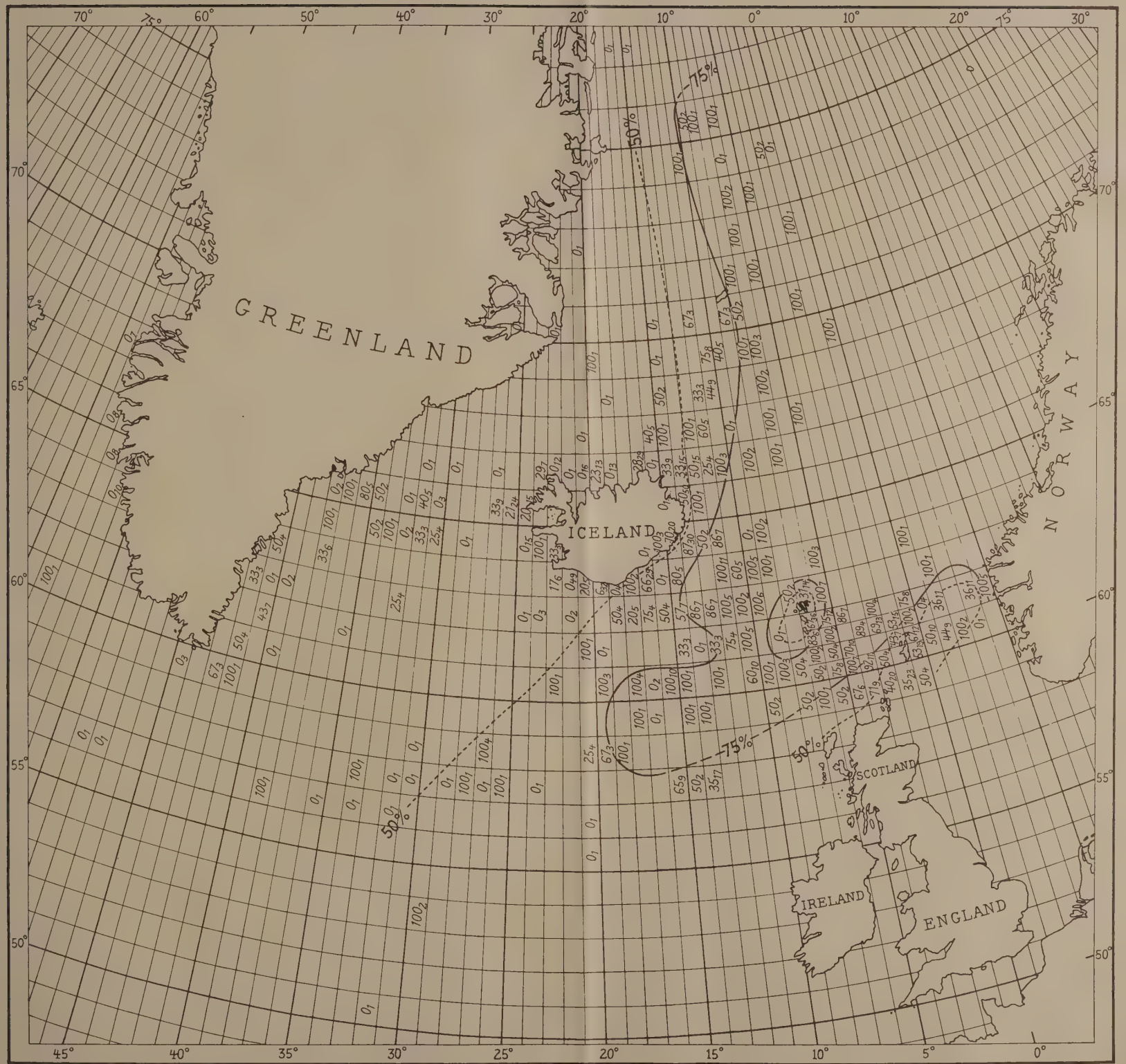
continued

Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
12/6-39	25	64°07′ N.—52°25′ W.	66°50′ N.—53°41′ W.	Greenland	27/7-39	45
			c. 65°02′ N.—52°20′ W.	—	1/7-39	19
			c. 68°00′ N.—53°30′ W.	—	31/8-39	80
13/6-39	25	65°27′ N.—53°30′ W.	68°05′ N.—52°00′ W.	Greenland	20/8-39	68
			66°54′ N.—52°50′ W.	—	31/7-39	48
			c. 68°00′ N.—53°30′ W.	—	12/8-39	60
			67°52′ N.—53°34′ W.	—	17/8-39	65
			65°50′ N.—53°19′ W.	—	July 39	c. 25
			65°40′ N.—53°09′ W.	—	2/7-39	19
			66°54′ N.—52°50′ W.	—	26/7-39	43
			66°51′ N.—53°39′ W.	—	18/7-39	35
7/6-39	25	60°27′ N.—47°55′ W.	—			
8/6-39	25	63°14′ N.—51°40′ W.	64°07′ N.—52°20′ W.	Greenland	10/11-39	155
			63°57′ N.—51°37′ W.	—	19/6-39	11
			c. 64°15′ N.—51°40′ W.	—	23/6-39	15
			c. 65°07′ N.—52°00′ W.	—	24/7-39	46
			c. 63°58′ N.—51°40′ W.	—	July 39	c. 40
			63°59′ N.—51°37′ W.	—	19/6-39	11
			63°45′ N.—51°32′ W.	—	28/6-39	20
			64°17′ N.—51°42′ W.	—	4/9-39	88
			64°03′ N.—51°39′ W.	—	22/6-39	14
			63°56′ N.—51°37′ W.	—	2/8-39	55
14/6-39	25	67°12′ N.—54°14′ W.	67°58′ N.—53°34′ W.	Greenland	12/10-39	120
			67°58′ N.—53°34′ W.	—	27/7-39	43
			67°58′ N.—53°34′ W.	—	29/9-39	107
			68°38′ N.—53°07′ W.	—	14/6-40	365
			66°55′ N.—54°30′ W.	—	10/7-39	26
			c. 68°10′ N.—53°05′ W.	—	1/9-39	79
			67°27′ N.—54°17′ W.	—	27/8-39	74
5/6-39	25	59°32′ N.—44°04′ W.	c. 64°23′ N.—51°40′ W.	Greenland	18/7-39	43
			60°44′ N.—47°22′ W.	—	23/6-39	18
			63°39′ N.—51°34′ W.	—	7/7-39	32
30/7-39	25	65°55′ N.—26°35′ W.	—			
31/7-39	25	65°35′ N.—28°11′ W.	61°12′ N.— 4°41′ E.	Norway	6/7-44	1801
31/7-39	25	65°25′ N.—34°20′ W.	—			
2/8-39	25	66°00′ N.—30°55′ W.	—			
8/8-39	25	66°22′ N.—14°01′ W.	c. 70°12′ N.—19°10′ E.	Norway	30/1-40	175
			c. 69°00′ N.—16°30′ E.	—	16/8-40	220
			64°35′ N.—10°45′ E.	—	22/12-39	136

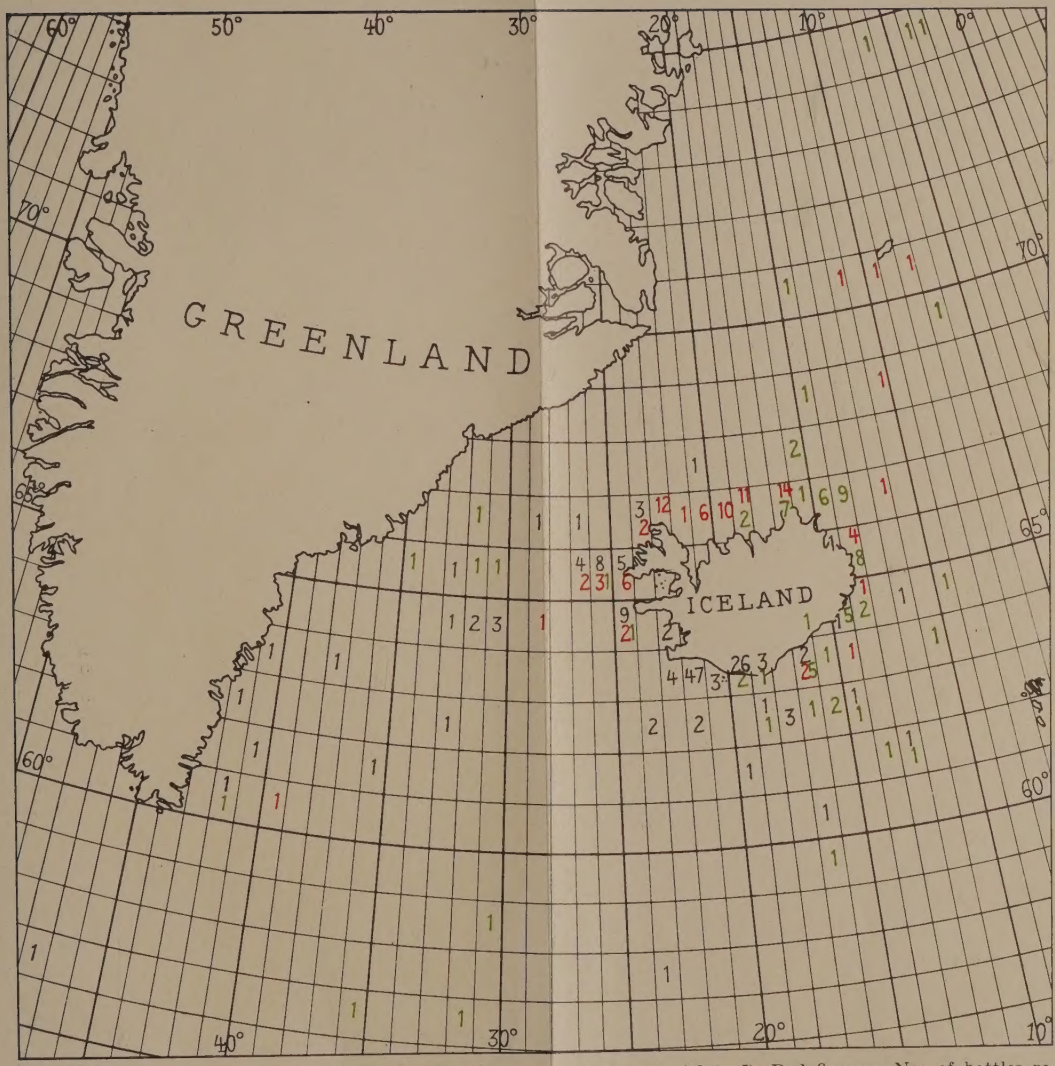
Liberations			Recoveries			Drift-Period (days)
Date	No. of bottles	Position	Position	Place	Date	
$^{10}/_{8}$-39	25	64°58′ N.—13°26′ W.	68°09′ N.—13°20′ E.	Norway	$^{27}/_{2}$-40	201
			c. 69°00′ N.—15°35′ E.	—	$^{4}/_{7}$-40	330
			71°03′ N.—26°06′ E.	—	$^{10}/_{6}$-40	306
			70°59′ N.—28°32′ E.	—	$^{12}/_{7}$-40	337
			63°23′ N. — 7°45′ E.	—	$^{28}/_{12}$-39	140
			67°14′ N.—14°33′ E.	—	$^{21}/_{6}$-40	316



No. of bottles recovered from each field of 1°. In the hatched fields bottles have been liberated but none of them was recovered.



No. of recoveries from Norway in percentage of all bottles recovered. The number of total recoveries from each field is added as index.



Recoveries from Iceland. Black figures: No. of bottles recovered on I_1 (plate I). Red figures: No. of bottles recovered on I_2 (plate I). Green figures: No. of bottles recovered on I_3 (plate I).

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